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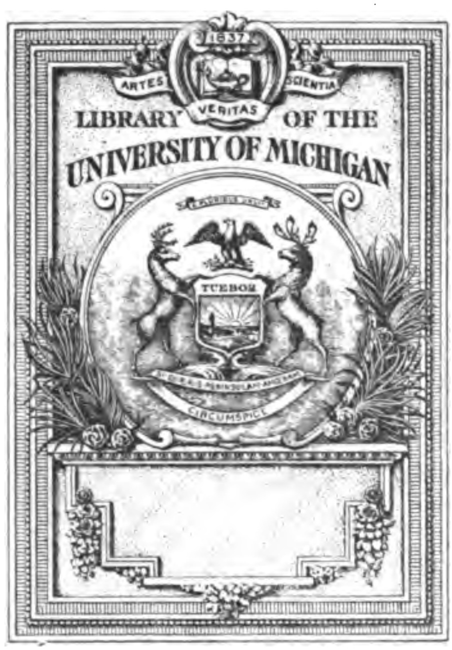
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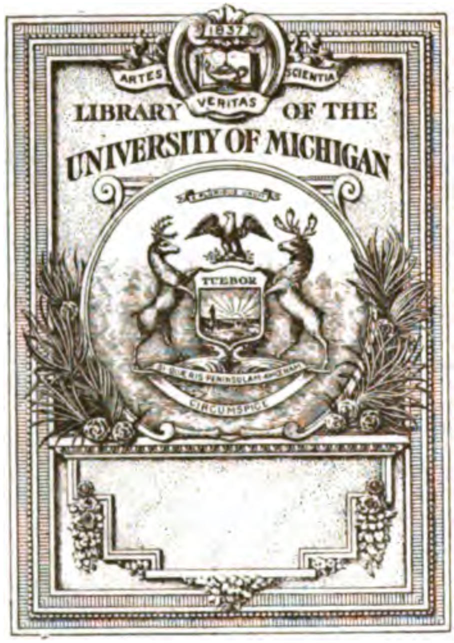
THE SCIENTIFIC MONTHLY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THE SCIENTIFIC MONTHLY

EDITED BY

J McKEEN CATTELL

VOLUME III

JULY TO DECEMBER, 1916

NEW YORK
THE SCIENCE PRESS
1916

PRESS OF
THE NEW ERA PRINTING COMPANY
LANCASTER, PA.

Vol. 3, No. 1 JULY, 1916

THE SCIENTIFIC MONTHLY

EDITED BY J. McKEEN CATTELL

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THE SCIENCE PRESS

LANCASTER, PA. GARRISON, N. Y.

NEW YORK: Sub-Station 84

Single Number, 30 Cents Yearly Subscription, $3.00

THE SCIENTIFIC MONTHLY

JULY, 1916

THE ORIGIN AND EVOLUTION OF LIFE UPON THE EARTH[1]

By Henry Fairfield Osborn

COLUMBIA UNIVERSITY, AMERICAN MUSEUM OF NATURAL HISTORY

LECTURE I. PART I

Introduction

WE may introduce this great subject by putting to ourselves four leading questions: first, is life something new; second, is life evolution the same as stellar evolution; third, is there evidence that similar physico-chemical laws prevail in life and in lifeless evolution; fourth, are life forms the result of law or of chance?

First: does the origin of life[2] represent the beginning of something new in the cosmos, or does it represent the continuation and evolution of forms of matter and energy already found in the earth, in the sun, and in the other stars? This is the first question which occurs to us, and it is one which has not yet been answered. The more traditional opinion is that something new entered this and possibly other planets with the appearance of life; this is also involved in all the older and newer hypotheses which group around the idea of vitalism or the existence of specific, distinctive and adaptive energies in living matter. The more modern scientific opinion is that life arose from a recombination of forces preexisting in the cosmos. To hold to this answer, that life does not represent the entrance either of a new form of matter or of a new series of laws but is simply another step in the general evolutionary process, is certainly consistent with the development of me-

[1] Fourth course of lectures on the William Ellery Hale Foundation, National Academy of Sciences, delivered at the meeting of the academy at Washington, on April 17 and 19, 1916. The author is greatly indebted for many notes and suggestions in physics and chemistry to his colleagues in the National Academy and Columbia University, especially to M. I. Pupin, F. W. Clarke, G. F. Becker and W. J. Gies.

[2] In order to consider this problem from a fresh, unbiased, and original point of view the author has purposely refrained from reading the recent treatises of Shafer, Moore and others on the origin of life. In the chemical section the author is, however, indebted to the very suggestive work of Henderson entitled "The Fitness of the Environment."

chanics, physics and chemistry since the time of Newton and of evolutionary thought since Lamarck and Darwin.

Second: the second question relates to the exact significance of the term *evolution* when applied to lifeless and to living matter. Is the development of life evolutionary in the same sense or is it essentially different from that of the inorganic world? Let us critically examine this question by comparing the evolution of life with what is known of the evolution of matter, of the evolution of the stars, of the formation of the earth; in brief, of the comparative anatomy and physiology of the universe as developed in the preceding lectures of this course by Rutherford,[3] Campbell,[4] and Chamberlin;[5] of the possible evolution of the chemical elements themselves from simpler forms, in passing from primitive nebulæ through the hotter stars to the planets, as first pointed out by Clarke[6] in 1873, and by Lockyer in 1874.

Do we find a correspondence between the orderly development of the stars and the orderly development of life? Do we observe in life a continuation of processes which in general have given us a picture of the universe slowly cooling off and running down; or, after hundreds of millions of years of more or less monotonous repetition of purely physicochemical and mechanical reaction, do we find that electrons, atoms, and molecules break forth into new forms and manifestations of energy which appear to be "creative," conveying to our eyes at least the impression of incessant genesis of new combinations of matter, of energy, of form, of function, of character?

To our senses it seems as if the latter view were the correct one, as if something new had been breathed into the aging dust, as if the first appearance of life on this planet marked an actual reversal of the previous order of things. Certainly the cosmic processes cease to run down and begin to build up, abandoning old forms and constructing new ones. Through these activities within matter in the living state the dying earth, itself a mere cinder from the sun, develops new chemical compounds; the chemical elements of the ocean are enriched from new sources of supply, as additional amounts of chemical compounds, produced by organisms from the soil or by elements in the earth that were not previously dissolved, are liberated by life processes and ultimately carried out to sea; the very composition of the rocks is changed; a new life crust begins to cover the earth and to spread over the bottom of the sea. Thus our old inorganic planet is reorganized, and we see in living matter a reversal of the melancholy conclusion reached by Campbell[7] that

[3] Rutherford, Sir Ernest, 1914.

[4] Campbell, William Wallace, 1914.

[5] Chamberlin Thomas Chrowder, 1916.

[6] Clarke, F. W., 1873, p. 323.

[7] Campbell, William Wallace, 1915, p. 209.

Everything in nature is growing older and changing in condition; slowly or rapidly, depending upon circumstances; the meteorological elements and gravitation are tearing down the high places of the earth; the eroded materials are transported to the bottoms of valleys, lakes and seas; and these results beget further consequences.

Thus, in answer to our second question, it certainly appears that *living matter does not follow the old evolutionary order* but represents a new assemblage of energies and new types of action, reaction, and interaction—to use the terms of Newton—between those chemical elements which are as old as the cosmos itself, unless they prove to represent, as Clarke, Lockyer, and Rutherford have suggested, an evolution from still simpler elements.

Third, is there a continuation of the same physico-chemical laws? Yes, so far as we observe, the process is still *evolutionary rather than creative,* because all these new characters and forms invariably arise out of new combinations of preexisting matter and appear to broadly conform to the laws of thermodynamics, and especially to Newton's third law. According to the interpretation by Pupin of this third law of Newton, *action* and *reaction* refer to what is going on between material parts in actual contact, whereas *interaction* refers to what is going on between two material parts which are connected with each other by other parts. Action and reaction are simultaneous, whereas interaction refers to an action and reaction which are not simultaneous. For example, when one pulls at a line the horse feels it a little later than the moment at which the line is pulled; there is interaction between the hand and the horse's mouth, the line being the interconnecting part.

In this lecture I shall attempt to show that since in their *simple* forms living processes are known to be physico-chemical and are more or less clearly interpretable in terms of action, reaction and interaction, we are compelled to believe that *complex* forms will also prove to be interpretable in the same terms.

If we affirm that the entire trend of our observation is in the direction of the physico-chemical rather than of the vitalistic hypotheses this is very far from affirming that the explanation of life is purely materialistic or that any present physico-chemical explanation is either final or satisfying to our reason. Chemists and biological chemists have very much more to discover. May there not be in the assemblage of cosmic chemical elements necessary to life, which we shall distinguish as the *"life elements,"* some *known* element which thus far has not betrayed itself in chemical analysis? This is not impossible, because a known element like radium, for example, might well be wrapped up in living matter but as yet undetected, owing to its suffusion or presence in excessively small quantities or to its possession of qualities that have escaped notice. Or, again, an *unknown* chemical element, to which the

hypothetical term *bion* might be given, may lie awaiting discovery within this complex of known elements. Or an unknown source of energy may be active here. Or, as is far more probable from our present state of knowledge, unknown principles of action, reaction and interaction may await discovery: such principles are indeed adumbrated in the as yet partially explored activities of the catalytic agents in living chemical compounds.

In answer to our first main question, to which we now return, we may express as our own opinion, based upon the logical application of uniformitarian evolutionary principles, that when life appeared some energies preexisting in the cosmos were brought into relation with the elements or forces already existing. In other words, since every advance thus far in the quest as to the nature of life has been in the direction of a physico-chemical rather than a vitalistic explanation, from the time when Lavoisier (1743–1794) put the life of plants on a solar-chemical basis, logically following the same direction, we believe that the last step into the unknown—one which possibly may never be taken by man—will also be physico-chemical in all its measurable and observable properties, and that the origin of life, as well as its development, will ultimately prove to be a true evolution within the preexisting cosmos.

None the less, such evolution, we repeat with emphasis, is not like that of the chemical elements or of the stars; the evolutionary process now takes an entirely new and different direction. Although it arises through combinations of preexisting energies it is essentially constructive and creative; it is continually giving birth to an infinite variety of new forms and functions which never appeared in the universe before. While this creative power is something new derived from the old, it presents the first of the numerous contrasts between the living and the lifeless world.

We are now prepared for the fourth of our leading questions. It having been determined that the evolution of non-living matter follows certain physical laws and that the living world conforms to many if not to all of these laws the final question which arises is: does the living world also conform to law in its most important aspect, namely, that of fitness or adaptation, or does law emerge from chance?

Let us first make clear the distinction between law and chance. On this a physicist (M. I. Pupin) observes:

> In physics, when distinguishing between law and chance, we speak of coordinated phenomena like planetary motions, and of *non-coordinated* phenomena like the motion of individual molecules in a large number of molecules. In regard to such motion, chance or probability or so-called statistical modes of procedure guide the reasoning. Again, *radiation* is a statistical or non-coordinated mode of procedure, and since it is closely related to the growth of plants (the simplest forms of life) why is not life in its constituent elements a statistical or chance procedure? May not life-forms and life itself be differentiated just like the motion of radiating atoms and observable forms of radiation?

Although the motions giving rise to radiation are haphazard, the resulting forms of radiation which we observe are definite and beautifully arranged as if they proceeded from perfectly coordinated and not from perfectly haphazard motions.

It is obvious that the answer to these questions put by a physicist may be reached in biology through observation.

Campbell has described the orderly development of the stars and Chamberlin the orderly development of the earth: is there also an orderly development of life? Are life forms, like celestial forms, the result of law or are they the result of chance? This is perhaps the very oldest biologic question that has entered the human mind, and it is one on which the widest difference of opinion exists even to-day.

Chance has been the opinion held by a great line of philosophers from Democritus and Empedocles to Darwin, and including Poulton, de Vries, Bateson, and many others of our own day: chance is the very essence of the Darwinian selection hypothesis of evolution. William James[8] and many other eminent philosophers have adopted the "chance" view as if it had been actually demonstrated, instead of being, as it is, one of the string of hypotheses upon which Darwin hung his theory of the origin of adaptations and of species. To quote the opinion of a recent writer:

> And why not? Nature has always preferred to work by the hit or miss methods of chance. In biological evolution millions of variations have been produced that one useful one might occur.[9]

I have long maintained that this opinion is a biological dogma[10] which has gained credence through constant reiteration, for I do not know that it has ever been demonstrated through the actual observation of any evolutionary series.

Law has been the opinion of another school of natural philosophers, headed by Aristotle, the opponent of Democritus and Empedocles. This opinion has fewer philosophical and scientific adherents; yet Eucken,[11] following Schopenhauer, has recently expressed it as follows:

> From the very beginning the predominant philosophical tendency has been against the idea that all the forms we see around us have come into existence solely through an accumulation of accidental individual variations, by the mere blind concurrence of these variations and their actual survival, without the operation of any inner law. Natural science, too, has more and more demonstrated its inadequacy.

Unlike our first question as to whether the principle of life introduced something new in the cosmos, a question which is still in the stage of pure speculation, this fourth question of law versus chance in the

[8] James, William, 1902, pp. 437–439.

[9] Davies, G. R., 1916, p. 583.

[10] Biology like theology has its dogmas. Leaders have their disciples and blind followers. All great truths, like Darwin's law of selection, acquire a momentum which sustains half-truths and pure dogmas.

[11] Eucken, Rudolf, 1912, p. 257.

evolution of life is no longer a matter of opinion, but of direct observation. So far as law is concerned life forms are like those of the stars: their origin and development as revealed through paleontology go to prove that Aristotle was essentially right when he said that "Nature produces those things which, being continually moved by a certain principle contained in themselves, arrive at a certain end."[12] What this internal moving principle is remains to be discovered. We may first exclude the possibility that it acts either through supernatural or teleologic interposition; and although its visible results are in a high degree purposeful we may exclude as unscientific the vitalistic theory of an *enteleche* or any other form of distinct internal perfecting agency. The fact that the principle underlying many complex forms of adaptation is still unknown, unconceived, and perhaps inconceivable, does not inhibit our opinion that adaptation will prove to be a continuation of the previous cosmic order. Since certain forms of adaptation which were formerly mysterious can now be explained without the assumption of an *enteleche,* it follows that all forms of adaptation may some day be explained in the same way.

But if we reject the vitalistic hypotheses we are driven back to the necessity of further physico-chemical analysis and research.

We shall discover that the first striking phenomenon in life is the *extraordinary complexity of the actions, reactions and interactions of forces which gradually evolves.* This complex of four interrelated sets of physico-chemical energies which I have previously adumbrated[13] as the most fundamental biologic law may now be restated as follows:

Actions, Reactions and Interactions of 1. The Cosmic Environment (physico-chemical energies). 2. The Individual Development (biochemical energies of the developing individual). 3. The Chromatin (biochemical energies of the hérédity substance). 4. The Life Environment (biochemical energies of other individuals).	*Selection* Competition with other individuals (factors of Natural Selection and Elimination, leading to survival or extinction).

This law I shall put forth in different aspects as the central thought of these lectures, stating at the outset that it involves an unknown prin-

[12] Osborn, H. F., 1894, p. 56.

[13] In several previous statements and definitions of this law I have termed it the law of the four inseparable factors of evolution, including environment (organic and inorganic), individual development, heredity (the chromatin) and selection. I now perceive that selection should not be included with the other factors because it is no sense coordinate. The causes of the origin and evolution of life must lie entirely within the physico-chemical and biochemical cycle. Osborn, H. F.

ciple, namely, the nature of the action, reaction, and interaction of the cosmic and life environment and individual developmental energies with the energies of the heredity substance. The nature of this unknown principle,[14] which is at present almost entirely beyond the realm of observation and experiment, will, however, be made clearer through the development of our main subject, the *origin and evolution of life upon the earth so far as it has been observed up to the present time or so far as it can be legitimately inferred from actual observation.*

The Earth as a Developing Environment

In general, our narrative will follow the "uniformitarian" method of interpretation first presented in 1788 by Hutton,[15] who may be termed the Newton of geology, and elaborated in 1830 by Lyell,[16] the master of Charles Darwin. In the spirit of the preparatory work of the great pioneers in geology, such as Hutton, Scrope and Lyell, and of the history of the evolution of the working mechanism of organic evolution, as developed by Darwin and Wallace,[17] our inferences as to past processes are founded upon the observation of present processes. The uniformitarian doctrine is this: present continuity implies the improbability of past catastrophism and violence of change, either in the inorganic or in the organic world.

We shall consider in order, first, the evolution of the inorganic environment necessary to life; second, the advent of life, what is known of its nature and in regard to the time and the form in which it probably originated; and third, the evolution of life, its orderly development, the differentiation and adaptation of the various life forms; while throughout we shall trace the operation of our fundamental biologic law, which involves the action, reaction and interaction of environment and individual development with the forces of heredity.

PRIMORDIAL ENVIRONMENT—THE LIFELESS EARTH

Let us first look at the cosmic environment, the inorganic world before the entrance of life. Since 1825, when Cuvier[18] published his famous "Discours sur les Revolutions de la Surface du Globe," the past history of the earth, of its waters, of the atmosphere, and of the sun—the four great complexes of inorganic environment—has been written with some approach to precision. Astronomy, physics, chemistry, geology and paleontology have each followed along their respective lines of observation, resulting in some concordance and much discordance of opinion and theory. In general we shall find that opinion founded

[14] See Osborn, H. F., 1909, 1912, 1, 1912, 2.

[15] Hutton, James, 1795.

[16] Lyell, Charles, 1830.

[17] Judd, John W., 1910.

[18] Cuvier, Baron Georges L. C. F. D., 1825.

upon life data has not agreed with opinion founded upon physical or chemical data. Discord has arisen especially in connection with the age of the earth and the stability of the earth's surface. In our review of these matters we may glance at opinions of all kinds, whatever their source; but our main narrative of the chemical origin and history of life on the earth will be followed by observations on living matter as it is revealed in paleontology and as it exists to-day, and not on hypotheses and speculations upon preexisting states.

The formation of the earth's surface is a prelude to our considering the first stage of the environment of life. According to the planetesimal theory, as set forth by Chamberlin[19] in the preceding lectures, the earth, instead of consisting of a primitive molten globe as postulated by the old nebular hypothesis originated in a nebulous knot of solid matter as a nucleus of growth which was fed by the infall or accretion of scattered nebulous matter (planetesimals) coming within the sphere of control of this knot. The temperature of these accretions to the early earth could scarcely have been high, and the mode of addition of these planetesimals one by one explains the very heterogeneous matter and differentiated specific gravity of the continents and oceanic basins. The present form of the earth's surface is the result of the combined action of the lithosphere, hydrosphere, and atmosphere. Liquefaction of the rocks occurred locally and occasionally as the result of heat generated by increased pressure and by radioactivity; but the planetesimal hypothesis assumes that the elastic rigid condition of the earth, as at present, prevailed—at least in its outer half—throughout the history of its growth from the small original nebular knot to its present proportions and caused the permanence of its continents and of its oceanic basins. We are thus brought to conditions that are fundamental to the evolution of life on the earth. According to the opinion of Chamberlin cited by Pirsson and Schuchert,[20] life on the earth may have been possible when it attained the present size of Mars.

According to Becker,[21] who follows the traditional theory of a primitive molten globe, the earth first presented a nearly smooth, equipotential surface, determined not by its mineral composition, but by its density. As the surface cooled down a temperature was reached at which the waters of the gaseous envelope united with the superficial rocks and led to an aqueo-igneous state. After further cooling the second and final consolidation followed, dating the origin of the granites and granitary rocks. The areas which cooled most rapidly and best conducted heat formed shallow oceanic basins, whereas the areas of poor conductivity which cooled more slowly stood out as low continents. The internal heat of the cooling globe still continues to do its work, and the

[19] Chamberlin, Thomas Chrowder, 1916.

[20] Pirsson, Louis V., and Schuchert, Charles, 1915, p. 535.

[21] Becker, George F., letter of October 15, 1915.

cyclic history of its surface is completed by the erosion of rocks, by the accumulation of sediments, and by the following subsidence of the areas loaded down by these sediments. It appears that the internal heat engine is far more active in the slowly cooling continental areas than in the rapidly cooling areas underlying the oceans, as manifested in the continuous outflows of igneous rocks, which, especially in the early history of the earth—at or before the time when life appeared—covered the greater part of the earth's surface. The ocean beds, being less subject to the work of the internal heat engine, have always been relatively plane; except near the shores, no erosion has taken place.

The Age of the Earth

The age of the earth as a solid body affords our first instance of the very wide discordance between physical and biological opinion. Among the chief physical computations are those of Kelvin, Sir George Darwin, and King and Barus.[22] In 1879 Sir George Darwin allowed 56 million years as a probable lapse of time since the earth parted company with the moon, and this birthtime of the moon was naturally long prior to that stage when the earth, as a cool crusted body, became the environment of living matter. Far more elastic than this estimate was that of Lord Kelvin, who, in 1862, placed the age of the earth as a cooling body between 20 and 400 million years, with a probability of 98 million years. Later, in 1897, accepting the conclusions of King and Barus calculated from data for the period of tidal stability, Kelvin placed the age limit between 20 and 40 million years, a conclusion very unwelcome to evolutionists.

As early as 1859 Charles Darwin led the biologists in demanding an enormous period of time for the processes of evolution, being the first to point out that the high degree of evolution and specialization seen in the invertebrate fossils at the very base of the Paleozoic was in itself a proof that pre-Paleozoic evolution occupied a period as long as or even longer than the post-Paleozoic. In 1869 Huxley renewed this demand for an enormous stretch of pre-Cambrian time; and as recently as 1896 Poulton[23] found that 400 million years, the greater limit of Kelvin's original estimate, was none too much. Later physical computations greatly exceeded this biological demand, for in 1908 Rutherford[24] estimated the time required for the accumulation of the radium content of a uranium mineral found in the Glastonbury granitic gneiss of the Early Cambrian as no less than 500 million years.

This estimate of the age of the Early Cambrian is eighteen times as great as that attained by Walcott[25] in 1893 from his purely geologic

[22] Becker, George F., 1910, p. 5.
[23] Poulton, Edward B., 1896, p. 808.
[24] Rutherford, Sir Ernest, 1906, p. 189.
[25] Walcott, Charles D., 1893, p. 675.

computation of the time rates of deposition and maximum thickness of strata from the base of the Cambrian upwards; but recent advances in our knowledge of the radioactive elements preclude the possibility of any trustworthy determination of the age of the elements through the methods suggested by Joly and Rutherford.

We thus return to the estimates based upon the time required for the deposition of stratified rocks as by far the most reliable, especially for our quest of the beginning of the life period, because erosion and sedimentation imply conditions of the earth, of the water, and of the atmosphere more or less comparable to those under which life is known to exist. These geologic estimates, which begin with that of John Phillips in 1860, may be tabulated as follows:

TIME REQUIRED FOR THE PROCESSES OF PAST DEPOSITION AND OF SEDIMENTATION AT RATES SIMILAR TO THOSE OBSERVED AT THE PRESENT DAY[26]

1860.	John Phillips	38– 96 million years.
1890.	De Lapparent	67– 90 million years.
1893.	Walcott (27,640,000 years since the base of the Cambrian Paleozoic; 17,5000,000 years or upwards for the pre-Paleozoic.)	55– 70 million years.
1899.	Geikie (Minimum 100 million years; maximum—slowest known rates of deposition—400 million years.)	100–400 million years.
1909.	Sollas (The larger estimate of 80 million years on the theory that pre-Paleozoic sediments took as much time as those from the base of the Cambrian upwards, allowing for gaps in the stratigraphic column.)	34– 80 million years

These estimates give a maximum of 64 miles as the total amount of sedimentation, which is equivalent to a layer 2,300 feet thick over the entire face of the earth.[27] From these purely geologic data the time ratio of the entire life period is now calculated in terms of millions of years, assuming the approximate reliability of the geologic time scale. The actual amount of rock weathered and deposited was probably far greater than that which has been preserved.

In general these estimates are broadly concordant with those reached by an entirely different method, namely, the amount of sodium chloride (common salt) contained in the ocean, to understand which we must take another glance at the primordial earth.

The lifeless primordial earth can best be imagined by looking at the lifeless surface of the moon, featured by volcanic action with little erosion or sedimentation. The surface of the earth, then, was chiefly

[26] Becker, George F., 1910, pp. 2, 3, 5.

[27] Clarke, F. W., 1916, p. 30.

spread with the granitic batholiths and the more superficial volcanic outpourings. There were volcanic ashes; there were gravels, sands, and micas derived from the granites; there were clays from the dissolution of granitic feldspars; there were loam mixtures of clay and sand; there was gypsum from mineral springs. Bare rocks and soils were inhospitable ingredients for any but the most rudimentary forms of life, such as were adapted to feed directly upon the chemical elements and their simplest compounds or to transform their energy without the friendly aid of sunshine. The only forms of life to-day which can exist in such an inhospitable environment as that of the lifeless earth are certain of the simplest bacteria.

It is interesting to note that in the period when the sun's heat was partly shut off by vapors the *early volcanic condition of the earth's surface* may have supplied life with fundamentally important chemical elements as well as with the heat-energy of the waters or of the soil. Volcanic emanations contain[28] free hydrogen, both oxides of carbon, and frequently hydrocarbons such as methane (CH_4) and ammonium chloride: the last compound is often very abundant. Volcanic waters sometimes contain ammonium (NH_4) salts, from which life may have derived its first nitrogen supply. In the Devil's Inkpot, Yellowstone Park, ammonium sulphate forms 83 per cent. of the dissolved saline matter: it is also the principal constituent of the mother liquor of the boric fumaroles of Tuscany, after the boric acid has crystallized out. A hot spring on the margin of Clear Lake, California, contains 107.76 grains per gallon of ammonium bicarbonate.

There were absent in the primordial earth the greater part of the fine sediments and detrital material which now cover three-fourths of the earth's surface, and from which a large part of the sodium content has been leached. The original surface of the earth was thus composed of igneous rocks to the exclusion of all others,[29] the essential constituents of these rocks being the lime-soda feldspars from which the sodium of the ocean has since been leached. Waters issuing from such rocks are, as a rule, *relatively* richer in silica than waters issuing from modern sedimentary areas. They thus furnished a favorable environment for the development of such low organisms (or their ancestors) as the existing diatoms, radiolarians, and sponges. These have skeletons composed of hydrated silica, mineralogically of opal.

The decomposition and therefore the erosion of the massive rocks was slower then than at present for none of the life agencies of bacteria, of algæ, of lichens, and of the higher plants, which are now at work on granites and volcanic rocks in all the humid portions of the earth, had yet appeared. On the other hand, much larger areas of these rocks were exposed than at present. In brief, to imagine the primal

[28] Clarke, F. W., 1916, Chap. VIII., also pp. 197, 199, 243, 244.

[29] Becker, George F., 1910, p. 12.

earth we must deduct all those portions of mineral deposits which as they exist to-day are mainly of organic origin, such as the organic carbonates and phosphates of lime,[30] the carbonaceous shales as well as the carbonaceous limestones, the graphites derived from carbon, the silicates derived from diatoms, the iron deposits made by bacteria, the humus of the soil containing organic acids, the soil derived from rocks which are broken up by bacteria, and even the ooze from the ocean floor, both calcareous and siliceous, formed from the shells of foraminifera and the skeletons of diatoms. Thus, before the appearance of bacteria, of algæ, of foraminifera, and of the lower plants and lowly invertebrates, the surface of the earth was totally different from what it is at present; and thus the present chemical composition of terrestrial matter, of the sea, and of the air, as indicated by Table I, is by no means the same as its primordial composition sixty million years ago.

TABLE I

AVERAGE DISTRIBUTION OF THE ELEMENTS IN EARTH, AIR AND WATER AT THE PRESENT TIME[31]

	Lithosphere, 93 Per Cent.	Hydrosphere, 7 Per Cent.	Atmosphere	Average, Including Atmosphere
Oxygen	47.17	85.79	20.8 (variable to some extent)	49.85
Silicon	28.00	......	....	26.03
Aluminum	7.84	......	....	7.28
Iron	4.44	......	....	4.12
Calcium	3.42	.05	....	3.18
Magnesium	2.27	.14	....	2.11
Sodium	2.43	1.14	....	2.33
Potassium	2.49	.04		2.33
Hydrogen	.23	10.67	variable	.97
Titanium	.44	......	....	.41
Carbon	.19	.002	variable	.19
Chlorine	.06	2.07	....	.40
Bromine	....	.008	....	
Phosphorus	.11	......	....	.10
Sulphur	.11	.09	....	.10
Barium	.09	......	....	.09
Manganese	.08	......	....	.08
Strontium	.03	......	....	.03
Nitrogen	....	......	78.0 (variable to some extent)	.03
Fluorine	.10	......	....	.10
All other elements	.50	......	....	.47

[30] It seems improbable that organisms originally began to use carbon or phosphorus in *elementary* form: carbonates and phosphates were probably available at the very beginning and resulted from oxidations of decompositions.—W. J. Gies.

Phosphate of lime, apatite, is an almost ubiquitous component of igneous rocks, but in very small amount. In more than a thousand analyses of such rocks, the average percentage of P_2O_5 is 0.25 per cent.—F. W. Clarke.

[31] Clarke, F. W., 1916, p. 34.

In Table I all the "life elements" which enter more or less freely into organic compounds are indicated by italics, showing that life has taken up and made use of practically all the chemical elements of frequent occurrence with the exception of aluminum, barium and strontium, which are extremely rare in life compounds, and of titanium, which thus far has not been found in any. But even these elements appear in artificial organic compounds, showing combining capacity without biological "inclination" thereto. In the life compounds, as in the lithosphere and hydrosphere, it is noteworthy that the elements of least atomic weight predominate over the heavier elements.

PRIMORDIAL ENVIRONMENT—THE LIFELESS WATER

According to the theory of Laplace the waters originated in the primordial atmosphere; according to the planetesimal theory of Chamberlin[32] and Moulton[33] the greater volume has been gradually added from the interior of the earth through the vaporous discharges of hot springs. As Suess observes,

> The body of the earth has given forth its ocean.

From the beginning of Archeozoic time, namely, for eighty million years, we have little biologic or geologic evidence as to the stability of the earth. From the beginning of the Paleozoic, namely, for a period of thirty million years, the earth has been in a condition of such stability that the oceanic tides and tidal currents were similar to those of the present day; for the early strata are full of such evidences as ripple marks, beach footprints, and other proofs of regularly recurrent tides.[35]

As in the case of the earth, the chemistry of the seas is a matter of inference, *i. e.*, of subtraction. The relatively simple chemical content of the primordial seas must be inferred by deducting the mineral and organic products which have been sweeping into the ocean from the earth during the last eighty to ninety million years; and also by deducting those that have been precipitated as a result of chemical reactions, calcium chloride reacting with sodium phosphate, for example, to yield precipitated calcium phosphate and dissolved sodium chloride.[36] The present waters of the ocean are rich in salts which have been derived by solution from the rocks of the continents.

Thus we reach our first conclusion, namely: it is probable that life originated on the continents, either in the moist crevices of rocks or soils, in the fresh waters of continental pools, or in the slightly saline waters of the bordering primordial seas.

As long ago as 1715 Edmund Halley suggested that the amount of

[32] Chamberlin, Thomas Chrowder, 1916 .
[33] Moulton, F. R., 1912, p. 244.
[35] Becker, George F., 1910, p. 18.
[36] W. J. Gies.

salt in the ocean might afford a means of computing its age. Assuming a primitive fresh-water sea, Becker[37] in 1915 estimated the age of the ocean as between 50 and 70 million years, probably closer to the upper limit. The accumulation of sodium was probably more rapid in the early geologic periods than at the present time, because the greater part of the earth's surface was covered with the granitic and igneous rocks which have since been largely covered or replaced by sedimentary rocks, a diminution causing the sodium content from the earth to be constantly decreasing.[38] This is on the assumption that the primitive ocean had no continents in its basins and that the continental areas were not much greater than at the present time, namely, 20.6 per cent. to 25 per cent. of the surface of the globe.

AGE OF THE OCEAN CALCULATED FROM ITS SODIUM CONTENT[39]

1876.	T. Mellard Reade	
1899.	J. Joly	80– 90 million years.
1900.	J. Joly	90–100 million years.
1909.	Sollas	80–150 million years.
1910.	Becker	50– 70 million years.
1911.	F. W. Clarke and Becker	94,712,000 years.
1915.	Becker	60–100 million years.
1916.	Clarke	somewhat less than 100 million years.

From the mean of the foregoing computations it is inferred that the age of the ocean since the earth assumed its present form is somewhat less than 100 million years. The 63 million tons of sodium which the sea has received yearly by solution from the rocks has been continually uniting with its equivalent of chlorine to form the salt (NaCl) of the existing seas.[40] So with the entire present content of the sea, its sulphates as well as its chlorides of sodium and of magnesium, its potassium, its calcium as well as those rare chemical elements which occasionally enter into the life compounds, such as copper, fluorine, boron, barium—all these earth-derived elements were much rarer in the primordial seas than at the present time. Yet from the first the air in sea-water was much richer in oxygen than the atmosphere.[41] The primal sea was also devoid of those nitrogen compounds which are chiefly derived from the earth through the agency of the nitrifying bacteria. Those who hold to the hypothesis of the *marine origin* of protoplasm fail to account for the necessary proportion of nitrogenous matter there to begin with.

37 Becker, George F., 1910, pp. 16, 17.

38 Becker, George F., 1915, p. 201; 1910, p. 12.

39 After Becker, George F., 1910, pp. 3–5; and Clarke, F. W., 1916, pp. 150, 152.

40 Becker, George F., 1910, pp. 7, 8, 10, 12.

41 Pirsson, Louis V., and Schuchert, Charles, 1915, p. 84.

When we consider that these "chemical life elements," so essential to living matter, were for a great period of time either absent or present in a highly dilute condition in the ocean, it appears that we must abandon the ancient Greek conception of the origin of life in the sea, and again reach the conclusion that the lowliest organisms originated either in moist earths or in those terrestrial waters which contained nitrogen. Nitrates occasionally arise from the union of nitrogen and oxygen in electrical discharges during thunderstorms and were presumably thus produced before life began. Such nitrogen compounds, so essential for the development of protoplasm, may have been specially *concentrated* in *pools of water* to degrees particularly *favorable* for the *origin of protoplasm.*[42]

From terrestrial waters or soils life may have gradually extended into the sea. It appears, too, that every great subsequent higher life phase—the bacterial phase, the chlorophyllic algal phase, the protozoan phase—was also primarily of fresh-water and secondarily of marine habitat. It is probable that the succession of marine forms was itself determined to some extent by adaptation to the increasing concentration of saline constituents in sea-water. That the invasion of the sea upon the continental areas occurred at a very early period is demonstrated by the extreme richness and profusion of marine life at the base of the Cambrian.

As compared with primordial sea-water which was relatively fresh and free from salts and from nitrogen existing sea-water is an ideal chemical medium for life. As a proof of the special adaptability of existing sea-water to present biochemical conditions, a very interesting comparison is that between the chemical composition of the chief body fluid of the highest animals, namely, the blood serum, and the chemical composition of sea-water, as given by Henderson.[43]

CHEMICAL COMPOSITION OF SEA-WATER AND OF BLOOD SERUM

"Life Elements"	In Sea-water	In Blood Serum
Sodium	30.59	39.0
Magnesium	3.79	0.4
Calcium	1.20	1.0
Potassium	1.11	2.7
Chlorine	55.27	45.0
SO_4	7.66	
CO_3	0.21	12.0
Bromine	0.19	
P_2O_5		0.4

That life originated in water (H_2O) there can be little doubt. The

[42] Suggested by Professor W. J. Gies.

[43] Henderson, Laurence J., 1908, II., p. 145.

fitness of water is maximal[44] both as a solvent in all the bodily fluids, and as a vehicle for most of the other chemical compounds. Further, since water itself is a solvent that fails to react with many substances (with nearly all biological substances) it serves also as a factor of biochemical stability. Water and the carbon dioxide of the atmosphere are the common source of every one of the complicated organic compounds and also the common end products of the materials yielding energy to the body. Proteins are made from supplies containing nitrogen material in addition.

In relation to Newton's law of action, reaction and interaction the most important property of water is its dielectric constant. Although itself only to a slight degree dissociated into ions it is the bearer of dissolved electrolytic substances and possesses a high power of electric conductivity, properties of great importance in the development of the electric energy of the molecules and atoms in ionization. Thus water is the very best medium of electric ionization in solution, and was probably essential to the mechanism of life from its very origin.[45]

Through all the electric changes of its contained solvents water itself remains very stable because the molecules of hydrogen and oxygen are not easily dissociated; their union in water contributes to the living organism a series of properties which are the prime conditions of all physiological and functional activity. The great surface tension of water as manifested in capillary action is of the highest importance to plant growth; it is also an important force acting within the formed colloids, the protoplasmic substance of life.

PRIMORDIAL ENVIRONMENT—THE ATMOSPHERE

It is significant that the simplest known living forms derive their "life elements" partly from the earth, partly from the water, and partly from the atmosphere. This was not improbably true also of the earliest living forms.

One of the mooted questions concerning the primordial atmosphere[46] is whether or no it contained free oxygen. The earliest forms of life were probably dependent on atmospheric oxygen, although certain existing bacterial organisms, known as "anærobic," are now capable of existing without it.

The primordial atmosphere was heavily charged with water vapor (H_2O) which has since been largely condensed by cooling. In the early period of the earth's history volcanoes[47] were also pouring into the atmosphere much greater amounts of carbon dioxide (CO_2) than at the

[44] These notes upon water are chiefly from the very suggestive treatise "The Fitness of the Environment," by Henderson, Lawrence J., 1913.

[45] Henderson, Lawrence J., 1913, p. 256.

[46] Becker, George F., letter of October 15, 1915.

[47] Henderson, Lawrence J., 1913, p. 134.

present time. At present the amount of carbon dioxide in the atmosphere averages about three parts in 10,000, but there is little doubt that the primordial atmosphere was richer in this compound which next to water and nitrogen is by far the most important both in the origin and in the development of living matter. The atmospheric carbon dioxide is at present continually being reduced by the absorption of carbon in living plants and the release of free oxygen; it is also washed out of the air by rains. On the other hand, the respiration of animals is continually returning it to the air. The large amount of aqueous vapor and of carbon dioxide in the primordial atmosphere served to form an atmospheric blanket which inhibited the radiation of solar heat from the earth's surface and also prevented excessive changes of temperature. Thus there was on the primal earth a greater regularity of the sun's heat supply, with more moisture, while the light supply from the sun was less intense and constant than at present. This is in general accord with the fact that the most primitive organisms surviving upon the earth to-day, the bacteria, are rather dependent upon heat than upon light for their energy. It is also possible that through the agency of thermal springs and the heat of volcanic regions primordial life forms may have derived their energy from the heat of the earth rather than from that of the sun.

The stable elements of the present atmosphere, for which alone estimates can be given, are essentially as follows:[48]

	By Weight	By Volume
Oxygen	23.024	20.941
Nitrogen	75.539	78.122
Argon	1.437	.937
	100.000	100.000

Since carbon is a less essential element[49] in the life-processes of the simplest bacteria, we can not agree with Henderson[50] that carbon dioxide was coordinate with water as a primary compound in the origin of life. It probably was subsequently utilized in the chlorophyllic stage of plant evolution.

Atmospheric carbon dioxide (CO_2) which averages about three parts in every 10,000, and water (H_2O) is always present in varying amounts; beside argon, the rare gases helium, xenon, neon, and krypton are present in traces. None of the rare gases which have been discovered in the atmosphere, such as helium, argon, xenon, neon, krypton, and niton—the latter a radium emanation—are at present known to have any relation to the life processes. Carbon dioxide exists in the atmos-

48 Clarke, F. W., letter of March 7, 1916.

49 Jordan, Edwin O., 1908, p. 66.

50 Henderson, Lawrence J., 1913, pp. 138, 139.

phere as an inexhaustible reservoir of carbon, only slightly depleted by the drafts made upon it by the action of chlorophyllic plants or by its solution in the waters of the continents and oceans. Soluble in water and thus equally mobile, of high absorption coefficient, and of universal occurrence, it constituted a reservoir of potential energy for the development of plants and animals. Carbon dioxide in water forms carbonic acid, one of the few instances of biological decomposition of water. This compound is so unstable that it has never been obtained. Carbon dioxide is now produced not only within the atmosphere but also by the action of certain anærobic bacteria and molds without the presence of free oxygen, as, for example, through the catalytic action of zymase, the enzyme of yeast, which is soluble in water. Loeb[51] dwells upon the importance of the bicarbonates as regulators in the development of the marine organisms by keeping neutral the water and the solutions in which marine animals live. Similarly the life of fresh-water animals is also prolonged by the addition of bicarbonates.

Thus from the chlorophyllic stage onwards the compounds of carbon, hydrogen, and oxygen (C, H, O)[52] constitute a unique ensemble of fitness among all the possible chemical substances for the exchange of matter and energy both within the organism and between it and its environment. The "regulator" or "balancing" influence is exerted by the phosphates and upon the acidifying tendency of carbon dioxide. The carbon dioxide in respiration raises the hydrogen concentration of the blood. The phosphates restrain this tendency while the breathing apparatus, in response to stimulus from the respiratory center irritated by the hydrogen, throws out the excess of the latter.

51 Loeb, Jacques, 1906, pp. 96, 97.

52 Henderson, Lawrence J., 1913, pp. 71, 194, 195, 207, 231, 232.

(To be continued)

THE ANIMAL-BREEDING INDUSTRY

By Dr. RAYMOND PEARL

THE MAINE AGRICULTURAL EXPERIMENT STATION

ANIMAL-BREEDING as an industry lies at the foundation of animal husbandry, which in turn is a basic element of the art of agriculture. Before any of the domestic animals can be used to provide food or clothing for mankind, the animals themselves must be produced. It is the function of the art or craft of animal-breeding to *produce* the world's supply of domestic animals of all kinds.

An attribute of living organisms, which fundamentally differentiates them from non-living matter, is the faculty of self-reproduction. Certain cells of the body in all higher animals are able, under suitable conditions, to go through a process of development which has as its end result the production of a new individual of the race or species. Through these cells (known as reproductive cells, or gametes) the animal has the power of reproducing itself. A new and distinct individual existence is brought into the world. Nothing like this is known in the inorganic realm. The stone in the field is not capable, through any self-initiated or self-perpetuated activity, of causing the coming into existence of a new stone, essentially like itself in form, size, structure, chemical composition and every other quality. Only plants and animals—in other words, living things—can do this.

It is this fundamental attribute of self-reproduction which the art of animal-breeding makes use of for the benefit of mankind. The breeder attempts to direct and control the reproduction of certain species and varieties of animals which possess qualities that are of value. Thus the breeder of dairy cattle endeavors so to control and direct the reproduction of these animals that he shall be able to produce cows which will yield a large amount of milk. The beef-cattle breeder tries to produce animals which carry on their frames a large amount of meat of good edible quality. The sheep-breeder has for his object to bring about the plentiful reproduction of animals bearing a large amount of wool. And so on, always the breeder is trying to control, guide and direct a fundamental biological process (reproduction) in such way that the product may be most valuable to him in some direction, either utilitarian, æsthetic or other. The more complete this control is, and the more definitely it is directed towards a particular desired end, the greater is the success of the breeder.

Man's needs or fancies have led to the production of many and diverse breeds of the domestic animals. In every civilized country special breeds and sub-breeds or varieties have been developed to meet the particular conditions prevailing there. In the number of such specialized and diversified races of animals, all of which must have come originally from a very small number of unspecialized ancestral forms, is perhaps to be found the most striking measure of the degree to which man has developed and extended his control over the natural processes of reproduction. Some idea of the extent to which this differentiation and specialization of animals for particular ends has been carried may be gained from Table I. This table shows the number of different breeds and varieties of farm live stock which are found in the British Isles.[1] Some are local varieties, but still distinct. All these are essentially native British breeds. Other countries, especially the older ones, show in greater or less degree the same conditions. They have developed breeds of live stock to suit their own special needs and fancies.

TABLE I

SHOWING THE NUMBERS OF DIFFERENT BREEDS OF BRITISH LIVE STOCK

Kind of Stock	Number of Distinct British Breeds and Varieties
Horses	17
Beef cattle	13
Dairy cattle	7[2]
Sheep	34
Swine	8

It is evident from this table that the skill of the English breeder has well justified the reputation it has created for the British Isles as one of the chief sources of the pure-bred live stock of the world.

To produce the world's supply of domestic animals, which we have seen to be the business of the animal breeder, is a task of great magnitude. Resort must be had to statistics[3] if any just conception is to be

[1] This table is compiled from "British Breeds of Live Stock," London (Board of Agriculture and Fisheries), 1910.

[2] Counting the Dairy Shorthorn as a distinct variety.

[3] The raw data on which the following statistical discussion is based are taken from the official returns of the U. S. Department of Agriculture, as published in the Yearbooks. The writer is, of course, responsible for the treatment of these figures here developed and for the deductions made.

The fact that the statistics here used are three years old in no wise invalidates the conclusions. Essentially the same conclusions would be reached from a survey of the stock-breeding industry in any normal year. Of course just at the present time industrial conditions of all sorts, including stock-breeding, are upset by war conditions. On that account, indeed, it is altogether probable that the facts as here presented give a much more nearly *normal* picture of the industry than would statistics for the years 1914 or 1915.

formed of the extent and importance of this breeding industry. We shall confine our attention to the United States, remembering that except in certain rather restricted lines, the animal-breeding industry in this country has as yet had no special or intensive development.

The following table shows the number of living domestic animals of various kinds which were on farms in the United States on January 1, 1912, together with their estimated farm value. The figures take no account of the vast numbers of horses, for example, which are not on farms.

TABLE II

NUMBER AND VALUE OF FARM LIVE STOCK IN THE UNITED STATES ON JANUARY 1, 1912

Kind of Stock	Number	Value
Horses	20,509,000	$2,172,694,000
Mules	4,362,000	544,359,000
Milch cattle	20,699,000	815,414,000
Other cattle (chiefly beef)	37,260,000	790,064,000
Sheep	52,362,000	181,170,000
Swine	65,412,000	523,328,000
Total	200,602,000	$5,027,029,000

Each one of these two hundred million animals was produced by a definite breeding operation. Somewhere somebody, with more or less care and thought as to the result, mated together two animals to produce each one of the individuals or litters which lumped together give this enormous total. The mere statement of such large figures conveys little impression to the mind. Let us try by comparison to see what the figures really mean. If all the live stock on farms in the United States on January 1, 1912, had been sold at a price such as to realize the estimated farm value in cash, and then the money so obtained had been equally divided, each individual man, woman and child in the country would have received as his share from this transaction $54.66. Furthermore the farm value of live stock represented an amount sufficient to pay the whole principal of the public debt of the United States (equal to $2,906,750,548.66 on October 1, 1913) nearly twice over.

This same sum of money would support the common schools of the United States for more than 12 years, assuming the same rate of school expenses as obtained in 1908–09. The mules or the swine each alone, if converted into cash, would pay all the common school expenses for more than a year, the cattle for four years, and the horses more than five years. The sheep of the country on January 1, 1912, were worth more than one and a half times as much as the entire property (lands, buildings, equipment, etc.) of all the colleges of agriculture and mechanic arts in the United States in 1910, the last year for which figures were available when this was written.

The figures given do not tell the whole story of the magnitude of the animal-breeding industry of the country. They deal only with the live stock actually on the farm. Besides this are the exports to be reckoned with. Table III. gives the facts regarding exports.

TABLE III

NUMBER AND VALUE OF LIVE STOCK EXPORTED FROM THE UNITED STATES DURING THE YEAR ENDING JUNE 30, 1911

Kind of Stock	Number	Value
Horses	25,145	$ 3,845,253
Mules	6,585	1,070,051
Cattle	150,100	13,163,920
Sheep	121,491	636,272
Swine	8,551	74,032
Total	311,872	$18,789,528

Over against the exports are to be set the imports. Animals are imported into the United States for purposes falling into two general classes. On the one hand, are the imports, mainly from European countries, of superior animals to be used as breeding stock. The ultimate object of such importation is the improvement of the live-stock of the country. On the other hand, there are some importations of animals for purposes of slaughter and utilization in other ways than breeding. The live-stock imports of each of these classes for the fiscal year 1910–11 are given in Table IV.

TABLE IV

NUMBER AND VALUE OF LIVE STOCK IMPORTED INTO THE UNITED STATES DURING THE YEAR ENDING JUNE 30, 1911

Kind of Stock	Why Imported	Number	Value
Horses	For breeding purposes	6,331	$2,055,418
"	" other "	3,262	636,656
Cattle	" breeding "	2,441	362,220
"	" other "	180,482	2,590,857
Sheep	" breeding "	5,341	116,277
"	" other "	48,114	261,348
Total	....	245,971	$6,022,776

From the figures given in the preceding tables it is possible to make some calculations to show average individual values. These are of interest because they furnish some indications of the cash value which rewards attention and care devoted to the breeding of animals. Let us first consider the average values of the different kinds of live stock on the farm. These figures will furnish a base with which comparison may be made. They measure in a crude way, but still a real one, the

stage of development or progress which the live stock breeding industry of the country has attained. Table V. gives the figures, calculated from the data given in Table II. above.

TABLE V

AVERAGE VALUES OF LIVE STOCK ON THE FARM

Kind of Stock	Average Value of the Individual
Horses	$105.94
Mules	124.80
Milch cows	39.39
Other cattle	21.20
Sheep	3.47
Swine	8.00

It is to be expected that animals chosen for export will be on the average of somewhat better quality than those left on the farm. A part go out of the country for breeding purposes, and these will have a powerful effect in raising the average value of exported stock. In accordance with expectation, the average values for exported stock are seen in Table VI. to be in every case somewhat greater than those for farm stock. The relative amount of this increase, shown as the percentage which the difference in values is of the farm value, is given for each class of stock in a third column of the table.

TABLE VI

AVERAGE VALUES OF LIVE STOCK EXPORTED

Kind of Stock	Average Value of Individual	Percentage Increase in Average Value of Exported Over Farm Live Stock
Horses	$152.92	44.3
Mules	162.50	30.2
Cattle	37.70	216.7[4]
Sheep	5.24	51.4
Swine	8.66	8.2

While the relative increases of value seen here are respectable, considered by themselves, they are insignificant in comparison with those exhibited in the valuation of animals *imported* for breeding purposes. The figures for the latter are shown in Table VII., which is calculated in the same way as Table VI.

TABLE VII

AVERAGE VALUES OF LIVE STOCK IMPORTED FOR BREEDING PURPOSES

Kind of Stock	Average Value of Individual	Percentage Increase in Average Value of Imported Over Farm Live Stock
Horses	$324.66	206.5
Cattle	148.39	435.8
Sheep	21.77	529.2

[4] Calculated on the basis of weighted mean of the two classes of cattle distinguished in Table V.

Taking these figures at their face value, for the moment, they indicate that the average horse imported into the United States for breeding purposes is worth twice as much as the average horse on an American farm. The average cow or bull imported is worth four and a third times as much as the average cow or bull on the farm; while the average imported sheep is more than five and a quarter times as valuable as the home product on the farm.

These figures furnish an impressive object lesson as to the value of paying attention to the breeding of live stock. Fundamentally the enhanced valuation of the imported animals rests on the fact that they are better bred than the average farm stock here. Their qualities all approach the ideal more closely. But they have been brought to that condition by the practise of skilful, well-planned and carefully executed breeding.

The statistical data so far presented regarding the breeding industry have been drawn from official returns and cover the country as a whole. They suffer from the defects of such statistics. While they show the general relations in a substantially correct way, they tend to reduce to a minimum differences of all kinds. In the case of the last comparison made, the indicated difference in average valuation between farm and live stock and that imported for breeding purposes is probably distinctly less than the true difference. A better comparison, and one which not only shows what careful breeding means to the farmer and to the nation as a source of wealth, but also shows that the foreigner has no monopoly on the production of fine breeding stock, is between average farm values and the prices realized at auction dispersal sales of pedigreed stock in this country. Let us examine a few figures of this kind.

Table VIII[5] gives the average sale price of pedigreed beef cattle in all sales held in this country during the six years preceding 1913.

The increase of these prices over the $21.00 of the farm cattle is obvious. The same considerations apply to other kinds of stock. At a Guernsey cattle sale held in Oconomowoc, Wisconsin, March 20, 1912, 69 head were sold at an average price of $377.26. Mr. H. E. Browning of Hersman, Ill., sold 41 Duroc-Jersey swine "of his own breeding" on December 19, 1912, at an average price of $173 per head. The contrast of this price with the $8.00 average on the farm is sufficiently striking.

The live-stock breeding industry of the world rests on a foundation of pure-bred pedigreed stock. The constant aim of the breeder from the earliest time has been to produce differentiated types particularly adapted to his locality, conditions and needs. Having once found or developed such a type, the breeder wishes to keep it. This he can only

[5] Compiled by the *Breeders' Gazette* and published in the issue of January 1, 1913.

TABLE VIII

AVERAGE PRICES REALIZED AT AUCTION SALES OF PEDIGREED BEEF CATTLE

Name of Breed	1912			1911			1910		
	No. of Sales	No. Sold	Av. Price	No. of Sales	No. Sold	Av. Price	No. of Sales	No. Sold	Av. Price
Short-horn	45	1,882	$177.40	53	2,258	$162.50	49	1,999	$187.50
Hereford	15	957	180.40	19	1,203	160.50	20	1,214	146.20
Aberdeen-Angus	12	627	138.95	13	723	143.60	19	995	167.35
Galloway	[a]...	...	......	[a]...	...	......	1	67	83.30
Polled Durham	2	83	132.85	1	42	140.60	3	74	115.00
Red Poll	1	30	107.25	[a]...	...	......	1	41	185.00

Name of Breed	1909			1908			1907		
	No. of Sales	No. Sold	Av. Price	No. of Sales	No. Sold	Av. Price	No. of Sales	No. Sold	Av. Price
Short-horn	78	3,308	$159.00	59	2,689	$146.50	84	3,608	$160.15
Hereford	25	1,398	127.05	15	936	116.15	29	1,358	123.70
Aberdeen-Angus	18	935	189.00	18	955	165.10	18	1,119	134.75
Galloway	2	69	128.05	3	136	84.50	3	123	139.05
Polled Durham	2	79	129.45	6	244	124.50	3	106	130.35
Red Poll	3	35	97.80	1	3	50.00	3	97	83.00

[a] No public sales reported.

do if it "breeds true." It obviously could not be expected to breed true if at frequent intervals it were crossed with other types. The breeding of individuals all of the same general type, and belonging to a few family lines, could be safely left to the individual breeder in the earlier days of the industry. With the wider development of the industry this was no longer possible. It became necessary to have an official registration of pedigrees, which should be beyond any chance of manipulation by the breeder. In this way one wishing to purchase an animal of a particular breed would have definite and objective evidence that the individual was, in fact, of the breed it was supposed to be.

Out of this need have grown the systems of pedigree registration in herd-books, stud-books and the like. In certain countries at the present time these registry records have an enhanced official status, because they are under governmental control and supervision. In the United States the control of live-stock registration is in some degree supervised by the Bureau of Animal Industry of the federal Department of Agriculture, particularly so far as concerns the registration of imported animals.

Under this system of pedigree registration an animal is regarded as "pure bred" if both its sire and dam are recorded in one of the officially recognized books of registration. No further biological criterion is demanded. A strict biological interpretation of the words "pure bred" would exclude many animals which are registered under the present system. The biological conception of hereditary "purity" has become much refined in recent years, and it now appears that the term "pure

bred" should apply in a strict sense to characters rather than to individuals.

The statistical data given in the foregoing discussion are by no means complete, but they serve sufficiently well the present purpose, which is simply to give some conception of the magnitude of the live stock breeding industry and its importance as a source of wealth to the nation. No account has been taken of other than farm live stock, and such obviously represents only a part of the animals which somebody has to breed to supply the needs of the people. Further nothing has been said about poultry, which represents an important industry in itself. Altogether, however, the following statement by Heape,[7] in concluding a review of the value of the breeding industry in England, is as well justified by conditions in this country, as in the country for which it was written. He says:

All I have attempted is, to give such a broad idea of the number and value of live stock in the kingdom, as the careful consideration of evidence I have been able to obtain, permits. I have taken the utmost care to avoid exaggeration, and in this, at any rate, I have reason to think I have succeeded.

When it is recollected that the Board of Agriculture returns are below, may be 10 per cent. or even more below the correct figures; when it is recollected what a large proportion of the people in the country, farmers, dealers, shopkeepers, farm-labourers, working men of various kinds, and gentlemen's servants, make their living in one way or another by means of stock; when it is recollected what a very large number of valuable animals there are in this country, as shown by a sale of yearlings at Newmarket, the prices obtained at the dispersal of a herd of Shorthorns or a flock of Southdowns, the value of a successful horse on the turf, of a good hunter, polo pony, pair of carriage-horses or cart-horses, of a couple of pointers, a spaniel, a bull-dog or lap-dog, etc., when such facts are borne in mind I do not think there can be found justification for objection to the final figures I have arrived at on the score of excess; and yet they show a total sum of nearly £450,000,000 invested in live stock in this country.

When to this is added the capital necessary to provide both buildings to house the stock, land on which to grow their food, barns, machinery, vehicles, harness and attendance, the total becomes so gigantic that I am surely justified in asserting: We have here an industry of enormous importance to the country, and one which merits far more attention than has ever yet been accorded to it; an industry to which, it must be remembered, "Science has never yet been applied."

[7] Heape, W., "The Breeding Industry," Cambridge, 1906.

THE REVERSUS, A FISHING TALE OF CHRISTOPHER COLUMBUS

By Dr. C. R. Eastman

American Museum of Natural History

TRULY a remarkable fish story that which should require an analysis of the earliest sources of American history in order to attest its credibility. Nevertheless there lies buried among the contemporary narratives that have come down to us of the second voyage of Columbus, in 1494, a tale of fish and fishermen of such interest and novelty, and apparent truthfulness, as will repay attention on the part of present-day students of history and natural science.

The original narrator of the fishing incident about to be described appears to have been Columbus himself. Unfortunately, however, the log or journal kept by the great navigator during his second voyage is no longer extant; but we possess abridgments of it in what passes for the "Life of Columbus," by his son Ferdinand, and also in the "History of the Indies" which we owe to that man of revered memory, Bartolomé de las Casas.

There has also been preserved for us a letter written by a naturalist who accompanied Columbus during his second voyage, Dr. Diego Alvarez Chanca; and much information derived from personal intercourse with the admiral and the men under his command is embodied in the writings of Peter Martyr of Anghera, sometimes styled the "father of American history," and in the chronicles of Andrés Bernaldez, curate of Los Palacios, in Andalusia. It is of record that Columbus placed his journals and other papers in the hands of Bernaldez, whose guest he was in 1496. Thirteen chapters of the curate's book are devoted to an account of Columbus and his discoveries. These, then, are the original sources to be consulted in regard to the happenings which took place during the memorable second voyage to the West Indies.

From the writings that have just been mentioned we learn that the Spaniards came upon a party of native fishermen off the coast of Cuba who were engaged in the capture of marine turtles, the means employed by them for that purpose being wholly unlike anything ever seen or heard of in Europe. In a word, it consisted in the use of a sucking-fish, known to naturalists as the *Remora,* which, after having been caught and tethered (so to speak) by means of a cord attached to its body, was allowed to fasten itself by its sucking disc to another fish or turtle, whereupon both were drawn in. Historians have frequently repeated the narrative, but only a single naturalist, Alexander von Humboldt,

appears to have inquired into the premises at all carefully. It may therefore be instructive for us to compare two or three of the different versions that are contained in the original sources, after which we may be better able to interpret the actual facts.

First of all it will be of interest to traverse in imagination with Columbus the route by which he steered his caravels amid the verdant, perfume-laden isles that dot the sea near Cuba, as he sailed westward in the month of May, 1494, with the project not only of finding a new route to India, but of actually sailing round the world. This we know from what Ferdinand Columbus tells us in a passage undoubtedly derived from his father's journal of the second voyage, "that if he had had abundance of provisions he would not have returned to Spain except by way of the East."[1] Through the irony of fate the Admiral was obliged to turn back from near that point where the fishing scene was witnessed, when two or three days more sailing would have proved to him the insular character of Cuba, and might have led to the immediate discovery of Yucatan, or Mexico.

We shall let Ferdinand tell us in his own language, which we may be sure follows very closely his father's journal, of what took place as the first European vessels to navigate along the southern coast of Cuba came upon the Queen's Gardens. The English rendering here given is found in the second volume of "Churchill's Voyages" (p. 536), and reads thus:

> On Saturday, the 3d of May, the Admiral resolved to sail over from Cuba to Jamaica, that he might not leave it behind without knowing whether the report of such plenty of gold they heard there was in it, prov'd true; and the wind being fair, and he almost half way over, discovered it on Sunday. Upon Monday he came to an anchor, and thought it the beautifullest island of any he had yet seen in the Indies, and such multitudes of people in great and small canoes came abroad that it was astonishing. . . .
>
> The wind being somewhat contrary, the Admiral could not make so much way as he wished, till on Tuesday the 13th of May he resolved to stand for Cuba, to keep along its coast, designing not to return till he had sailed 5 or 600 leagues, and were satisfied whether it were an island or continent. . . .
>
> The nearer they sailed to Cuba, the higher and pleasanter the little islands appeared which were all over that sea, and it being a matter of difficulty and to no purpose to give every one of them a name, the Admiral called them all in general *Jardin de la Reina*, the Queen's Garden. . . . In these islands they saw crows and cranes like those of Spain, the sea-crows [gulls], and infinite numbers of little birds that sung sweetly, and the air was as sweet as if they had been among roses, and the finest perfumes in the world; yet the danger was very great, there being such abundance of channels, that much time was spent in finding the way out.
>
> In one of these channels they spy'd a canoe of Indian fishermen, who very quietly, without the least concern, awaited the boat which was making towards them, and being come near, made a sign to them in it to attend till they had done fishing.

[1] "Hist." p. 166.

Their manner of fishing was so strange and new to our men, that they were willing to comply with them. It was thus: they had ty'd some small fishes they call *Reverso* by the tail, which run themselves against other fish, and with a certain roughness they have from the head to the middle of the back they stick fast to the next fish they meet; and when the Indians perceive it drawing their line, they hand them both in together. And it was a tortoise our men saw so taken by those fishermen, that fish [the Reverso] clinging about the neck of it, where they generally fasten, being by that means safe from the other fish biting them; and we have seen them fasten upon vast sharks.

When the Indians in the canoe had taken their tortoise, and two other fishes they had before, they presently came very friendly to the boat, to know what our men would have, and by their directions went along aboard the ships, where the Admiral treated them very courteously. . . .

Proceeding thence, and bearing up closer to Cuba, they saw tortoises of a vast bigness, and in such numbers that they covered the sea. At break of day they saw such a cloud of sea-crows that they darkened the sun, coming from the seaward to the island, where they all lighted; besides them, abundance of pigeons, and birds of other sorts were seen, and the next day there came such swarms of butterflies that they darkened the air, and lasted till night, when the rain carried them away. . . .

In the brief description which is here given of the captive "fisherman-fish," or Reverso, we are told that it has a peculiar asperity along the back. Ferdinand's "Historie" has not come down to us in its original Spanish form, but is known only in translations, the earliest being that of Ulloa, in Italian. It may be that the English rendering to the effect that the Reverso was armed with "a certain roughness from the head to the middle of the back" does not accurately convey the sense of the original. At all events a slightly different description is given in the French version, which reads: "certain petit poisson qui porte de piquants crochus se relevant à contresens de son corps," etc. The latter characterization agrees better with the porcupine-fish, or Diodon, than the Remora, and both are included under the term of "Reversus" by the "fathers" of ichthyology, one being called the spinous, and the other the anguilliform variety.

In the histories of Las Casas and Herrera we read practically the same account of fishing with the Reversus as that given by Ferdinand Columbus. Of similar purport, also, but closely agreeing in literary style with the writings of the famous discoverer, is the account of the same fishing scene in Queen's Gardens which we find in the chronicles of Andrés Bernaldez.[1] We now present this passage in English form.

CHAPTER CXXVI

Of a great number of Islands which were Discovered

The Admiral set sail [from Jamaica] with his three caravels, and sailed 24 leagues towards the west, as far as the gulf Buen Tiempo. . . . On Whitsunday, 1494, they stopped at a place which was uninhabited—but not from the inclemency of the sky, or the barrenness of the soil—in the midst of a large grove of palm-trees, which seemed to reach from the sea-shore to the very heavens.

[1] "Hist. Reyes Catól.," Cap. 126.

. . . Here they all rested themselves upon the grass about these fountains, enjoying the charming fragrance of the flowers, and the melody of the song of birds, so many and so sweet, and the shade of the palm trees, so tall and so beautiful, that the whole was a wonder. . . . As the number of islands in this region was so great that he could not give to each a separate name, the Admiral called them all by the common name of the Queen's Gardens.

On the day following, the Admiral being very desirous to fall in with some natives with whom he might parley, there came a canoe to hunt for fish:—for they call it hunting, and they hunt for one fish with others of a particular kind. They have certain fishes which they hold by a line fastened to their tails, and which are like conger-eels in shape, and have a large mouth [*i. e.*, head] completely covered with suckers, like the octopus. They are very fierce, like our ferrets, and when they are thrown into the water they fly to fasten themselves upon whatsoever fish they may espy, and sooner die than let go their hold till they are drawn out of the water.

The hunting fish is very light, and as soon as he has taken hold, the Indians draw him by the long cord attached to his body, and in this manner they take a fish each time on drawing both to the surface of the water.

As these hunters were at a distance from the caravel, the Admiral sent his boats to them with armed men, contriving it so that they should not escape to the land. As the boats came up to them, these hunters called out to the men in mildest manner and as unconcernedly as if they had known them all their lives, to hold off, because one of the fishes had fastened upon the under side of a large turtle, and they must wait till they had got it into the canoe. This our men did, and afterwards they took the canoe, and those in it, together with four turtles, each of which was three cubits in length, and brought them to the ships of the Admiral; and there they gave some account of these islands, and of their cacique who was close at hand, and had sent them to hunt. They asked the Admiral to go on shore, and they would make for him a great feast and would give him all of the four turtles they had caught.

Clearly the description just given refers to the "eel-like Reversus" or Remora, and so far as the description goes it is a more dependable sketch than the portrayal which Peter Martyr has preserved for us in the pioneer collection of voyages,[3] published in 1504, and "De Rebus Oceanis" of 1511. The following narrative is taken from the fifteenth chapter of the "Libretto":

Continuing [along the coast of Cuba] they found further onward some fishermen in certain of their boats of wood excavated like *zopoli*, who were fishing. In this manner they had a fish of a form unknown to us, which has the body of an eel and larger: and upon the head it has a certain very tender skin which appears like a large purse. And this fish they drag, tied with a cord to the edge of the boat, because it can not endure a breath of air. And when they see any large fish or reptile, they loosen the noose and this fish at once darts like an arrow at the fish or other creature, throwing over them this skin which he has upon his head; which he holds so firmly that they are not able to escape, and he does not leave them if they are not taken from the water; but as soon as he feels the air he leaves his prey and the fishermen quickly seize it. And in the presence of our people they took four large turtles which they gave our people for a very delicate food.

[3] "Libretto de Tutta la Navigatione de Re de Spagna, de le Isole et Terreni Novamente Trovati." The text for this libretto was written some time previous to the summer of 1501, and was reproduced in the fourth book of the "Paesi Novamente Retrovati," first published at Vicenza in 1507.

The entertaining writer whom we have just quoted gives a more elaborate account of this same incident, and manner of fishing with the Reversus, in the work by which he is best known, the "Decades of the Ocean," first published in 1511; but it is not necessary to follow these later modifications.

The next writer to treat of the same theme, with considerable enlargement of detail, is the well-known historian Oviedo, whose "Sumario" was published in 1516, and larger work on the "History of the Indies" in 1535. Oviedo gives a lively account of the intelligence of the "fisherman-fish," which he asserts was reared in captivity by the natives and trained to catch prey "as huntsmen or falconers use hounds or hawks in their game." But in his description of the fish itself Oviedo has strangely confused the characters of the sucking-fish with those of Diodon. Thus, he speaks of the "reverso" as being covered with imbricating scales, upon which are "certain prickles very sharp and strong, whereby he fastens himself to what fish he pleaseth; and these prickly scales he hath on most parts of his body."[4] Ferdinand Columbus also, as we have seen, describes the reverso as armed with backwardly pointing spines, which of course suggests Diodon. And it is Diodon that we find figured alongside of the Remora in sixteenth to eighteenth century ichthyological writings as if it were a second variety or "species" of the so-called "Reversus." Its curious antics on being hooked were first described by Père Du Tertre in 1657.[5]

One may inquire whence the name Reversus was derived; and the answer would seem to be that it is cognate in meaning with the classic name of the fish Remora, or Echeneis, which signifies "holding back."[6] That the Remora, or "ship-holder," actually impeded the progress of sailing vessels is an extremely ancient legend, which has survived to modern times.[7] The subject is illustrated in Greek and Roman ceramic art, and occurs repeatedly in classic as well as medieval literature. In the accompanying figure we have reproduced one of the earliest woodcuts in printed books depicting the Remora in the act of retarding a vessel; it is from the 1536 edition of the "Hortus Sanitatis." The illustration here given does not differ materially from that found in the *editio princeps* of this curious work, printed in 1479. The fishing scenes contained in the first editions respectively of the "Hortus Sanitatis" and "Dialouges of Ceatures Moralyzed" are probably the first of their kind to be introduced into printed books. Copies are also shown of Gesner's (1558) and Aldrovandi's (1638) representations of

[4] This sentence is taken from "Purchas his Pilgrimes," III., p. 994.

[5] "Hist. Antilles," II., p. 209.

[6] The Cuban naturalist Felipe Poey suggests that the name Reverso was applied by the Spaniards to the fish "parce que l'animal parait tourné *au rebours*, quand il se fixe." ("Hist. Nat. de Cuba," II., p. 249). Peter Martyr offers a like explanation.

[7] See Dr. Günther's article on the Remora, in *Ann. Mag. Nat. Hist.* for 1860, Ser. 3, Vol. 5, p. 386.

the Remora as a hunting-fish, and of Diodon appearing under the same guise.

How it happened that in the time of Columbus Diodon should become confused with Remora in the alleged capacity of a hunting-fish is a puzzling question. We may conjecture, however, that the porcupine-fish was among the number of specimens which, as Columbus tells

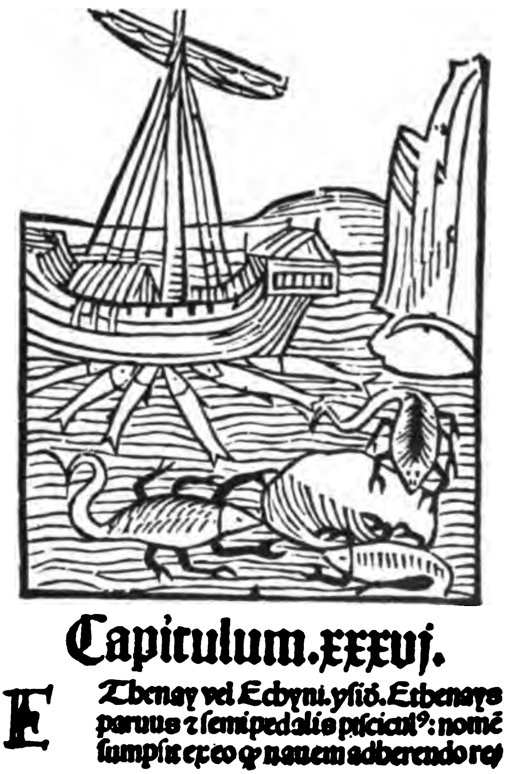

FIG. 1. EARLIEST KNOWN FIGURE INTENDED TO REPRESENT THE REMORA (*Echeneis*) OR "SHIP-STAYER," From the second edition of J. von Cube's "Hortus Sanitatis." Leipzig, 1490.

us in the journal of his first voyage, he ordered to be salted and carried back to Spain.[8] One of these was thought by Cuvier to have been the

[8] In the journal of the first voyage, part of the entry for Friday, November 16, 1492, reads as follows: "The sailors also fished with nets, and, among many others, caught a fish which was exactly like a pig, not like a tunny, but all covered with a very hard skin, without a soft place except the tail and the eyes, and an opening on the under side for voiding the superfluities. It was ordered to be salted, to bring home for the sovereigns to see."

Still earlier, under date of October 16, Columbus wrote this entry, which may be compared in style with the language quoted from Bernaldez in describing the Queen's Gardens:

"Here the fish are so unlike ours that it is wonderful. Some are of the shape of dories, and of the finest colors in the world, blue, yellow, red and other tints,

Figura hæc desumpta est ex tabula quadam descriptionis orbis terrarum.

FIG. 2. FISHING WITH THE REMORA, AS RELATED BY COLUMBUS. From Conrad Gesner's "Historiæ Animalium," Lib. IV, 1558.

trunk-fish; and another may well have been Diodon, these two forms being especially suitable for preservation, and as a matter of fact were well represented in the primitive museums of the time.[9] And being exhibited at the Court of Spain, one can conceive that the legend of the "reverso" became associated with this fish, and also the tale of its being trained for the capture of other fish.

So much for the original sources of the "Reversus" fishing incident: let us now consider its credibility. Humboldt, a century ago, gave full credence to the narrative, as related by Ferdinand Columbus, and conjectured that the species of sucking-fish employed by the natives at Queen's Gardens was probably *Echeneis naucrates*.[10] He also recalled that the French naturalist Commerson had noted among the inhabitants of Mozambique a similar use of the Remora for the capture of marine turtles; and cited Dampier (erroneously, however) and Captain Rogers to the same effect. From still another source, namely, the voyage of the Swedish traveler Andrew Sparrman,[11] we learn of African natives near the Cape of Good Hope making use of the Remora in identical manner for the capture of marine turtles.

all painted in various ways, and the colors are so bright that there is not a man who would not be astonished, and would not take great delight in seeing them. There are also whales. I saw no beasts in the island [of Cuba] of any kind, except parrots and lizards."

[9] See G. Brown Goode on "American Trunk-fishes," *Proc. U. S. Nat. Museum*, 1879, pp. 261–283.

[10] "Recueil d'Observ. Zool.," II., p. 192.

[11] "Voyage to the Cape of Good Hope." London, 1785. Paris, 1787. (French ed., II., p. 431.)

In order that the reader may judge of the similarity of the accounts of African and West Indian fishing with the Remora, we present at this point an English rendering of Commerson's observations. The original is found in Lacépède's treatise on Fishes.

> The Indian Remora, *Echeneis naucrates*, is very common about the coasts of Mozambique, where it is sometimes made use of for the following very singular manner of catching turtles. A ring is fastened round the tail of the fish, in such a manner as to prevent its escape, and a long cord fastened to the ring. When thus prepared, the fish is carried in a vessel of sea-water, and when the boatmen observe a turtle sleeping, as is the frequent habit of those animals, on the surface of the water, they approach as near as possible without disturbing it; and then throwing the Remora into the sea, and giving it the proper length of cord, it soon attaches itself to the under side of the sleeping turtle, which is thus easily drawn to the boat by the fishermen.[12]

The distinguished ichthyologist, Dr. Albert Günther, in referring to the accounts of Commerson and others, expresses doubt as to their genuineness, and states that they appear to have originated rather from an experiment than from regular practise. Dr. D. S. Jordan, also, doubts whether the large *Echeneis naucrates,* which he has studied in Cuba, was ever practically used in the manner described. We are permitted to quote the views of this authority as communicated in a personal letter. This reads in part:

FIG. 3. AN ILLUSTRATION FROM OGILBY'S AMERICA (1671) REPRESENTING THE SCENE DESCRIBED BY COLUMBUS IN FISHING WITH THE "REVERSUS" NEAR CUBA.

[12] Shaw's "General Zoology," 1808, II., p. 209.

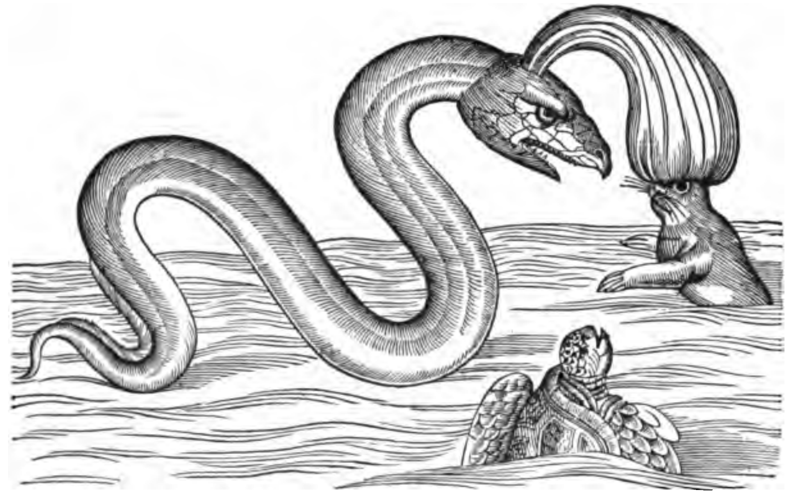

Fig. 4. The Remora, or eel-like variety of the Reversus. From Aldrovandis' "De Piscibus," 1628.

The minute the shark to which *E. naucrates* has fastened itself is drawn out of the water, it loosens its hold, and gets out of the way in a hurry. I do not think it could be trusted to fetch in a turtle, or any other large fish; and I never knew it to cling to any small fish. The smaller sucking-fish, *Remora remora,* clings tight. I have drawn up big sharks in the mid-Pacific with the Remora attached, and it wouldn't let go. Dr. Gilbert tells me that in Japan he has taken them off from sharks and kept them in the aquarium. They clung tight to the glass, not leaving it to swallow small fish until these came very close. But Remora, rarely exceeding 16 inches in length, could never be used in fishing and the big *Echeneis* doesn't "sit tight." The name "Reversus" seems to me to come from the fact that these fish, having black bellies, seem to be wrong-side up. Often when attached to other fish they are in that position.

On the other hand, some modern instances of fishing with the Remora have been reported, as for instance, the account published by Mr. Holmwood, a British consul in Madagascar, published in the *Proceedings of the London Zoological Society* for 1884, page 411. Dr. E. W. Gudger, who has been studying the Remora, has collected a number of apparently trustworthy observations; and Dr. Townsend, director of the New York Aquarium, has made practical tests of the adhesive power of these fishes. Dr. Townsend writes:

We used to catch a good many while I was cruising with the *Albatross.* When these fishes were thrown into tubes or buckets of sea water they took hold at once with their sucking discs and could not be detached without using considerable force. I have tied a stout cord around the tail of a two-foot Remora which attached itself to the inside of a two-gallon galvanized pail half-filled with water, and was then able to lift the pail, fish and water without the fish's grip giving way an inch. The pail and water weighed twenty-one pounds. The largest Remora in the aquarium is thirty-two inches long, and its cephalic disc is seven inches long and three inches wide. I have no doubt that with this fish attached to a good-sized sea turtle you could hand in the latter without difficulty.

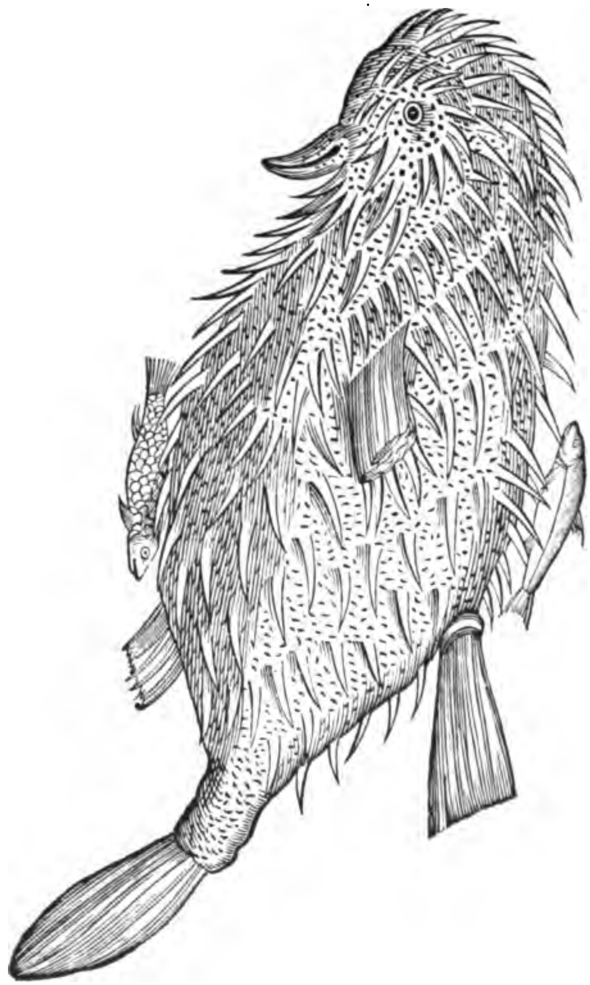

FIG. 5. DIODON, OR SO-CALLED "SPINOUS VARIETY OF THE REVERSUS." From Aldrovandis' "De Piscibus," 1638.

Another genus of sucking fish larger and more powerful than either the Remora or *Echeneis* is *Remiligia,* which apparently has the habit of attaching itself regularly to the bodies of Cetacea, and for that reason has come infrequently to the attention of ichthyologists.[13]

If we come now to form an opinion as to the credibility of the original narrative of the great discoverer, weighing it in the light of modern information, there would appear to be no sufficient reason for rejecting it as improbable or the creation of a florid imagination.

[13] See a note on *Remora australis* by John T. Nichols, in *Bull. Amer. Mus. Nat. Hist.*, XXXII., 1913, p. 182.

THE VARIABLE DESERT

By Dr. J. Arthur Harris

STATION FOR EXPERIMENTAL EVOLUTION, COLD SPRING HARBOR, N. Y.

SINCE 1903, the Desert Botanical Laboratory of the Carnegie Institution of Washington has served as a base for field excursions for many scientific men—not botanists merely, but geographers, geologists, physiographers, climatologists, zoologists and anthropologists. These men have come into personal contact with the southwestern deserts and have looked upon inert and living features with eyes trained for the most diverse sorts of details. Many of them have set forth in popular as well as in technical terms their impressions of these vast and scientifically fascinating regions of our national territory. To add another to the excellent descriptions of the region available from the pens of Coville, McGee, Hornaday, Huntington, Lloyd, Spaulding and MacDougal would be quite superfluous were it not for the fact that none of these men have, as it seems to me, emphasized in a few paragraphs the one essential feature of our southwestern deserts, which makes them possibly the best naturally equipped experimental laboratories which have been placed within the reach of American students of living things.

The striking characteristic of this whole region is heterogeneity, variability, contrast—whichever one may wish to call it. This is manifest in every fundamental element of the environmental substratum—geographic, physiographic, climatic, edaphic and biologic. Its consequences are discernible in every feature of the biological superstructure—floristic, morphologic, physiographic and genetic.

To the average reader, the word desert calls up the mental picture of a region of bare rocks and dry wind-swept sand, inhospitable to any but the toughest plant and intolerable to any but the hardiest animal. Such a desert presents to the imagination a landscape of the direst monotony—a landscape exactly the opposite of that of our southwestern deserts, which are filled with diversity and interest.

Geologically, the deserts of the general region of Tucson consist of a number of rugged mountain groups, varying greatly in age and composition, with their long detrital slopes and the alluvial valley of the Santa Cruz.

Biologically, the topography of a region is generally a far more important factor than its composition. Within easy reach of the Desert Laboratory are three ranges of mountains with elevations of 9,000 feet or over. Thus within a few miles of the lowest point in the Santa Cruz

valley there is a rise of roughly 6,500 feet. This necessarily means great variety of topography.

The biological covering of so diversified a terrain would be highly differentiated even in a region of the earth's surface in which rainfall is ample in amount and uniform in distribution. Here, irregularity and violence of rainfall is superimposed upon irregularity of surface and plays its part as a powerful environmental factor.

Leaving Tucson by any of the chief highways, one finds himself at once in vast stretches of mesa or of rocky slopes, showing everywhere the most striking marks of water action. To find a xerophytic vegetation in a region where records of water action are so conspicuous is a great surprise to the novice; yet the one is really the logical consequence of the other.

The twelve inches, more or less, of annual rainfall are divided between a season of gentler winter showers and another of torrential summer rains. The former leave very little evidence of their occurrence on the landscape. The latter are often very heavy and their eroding power very great. In one of these, quite unusual, to be sure, five inches of water fell—an amount constituting about half the total precipitation of that year and nearly equal in amount to the total rainfall of the dryest of thirty-one years recorded for Tucson.

The rocky hillsides with only scattered vegetation turn all but a small percentage of the water of these summer cloudbursts into the rocky gulches or canyons, which pass it on to the broad sandy arroyas traversing the long bajadas, transforming both, for a short time, into raging torrents which record their depth by the drift, or even large stones, lodged in the branches of the scrubby trees which mark their courses, in some places many feet above the sandy or gravelly floor, where one fries his bacon and spreads his sleeping bag in the dry season. Past the bajada slopes, the water flows over the broad valleys. Often these are of indeterminate drainage—fine examples of sheet flood erosion. Thus the less precipitous mountain slopes show long ragged gashes cut through the superficial detrital layer to the solid rock beneath, while the fine adobe soil of the apparently flat valleys show here and there areas where the sheet waters have last evaporated, alkali or salt spots, where the drainage is inadequate or sharply carved gutters, where the flatness is only apparent and the gradient really sufficient to give the flowing water considerable cutting power.

With so large a proportion of the total precipitation coming with violence, immediately running off the surface of the steeper slopes and rapidly sinking into the deeper underlying layers in the valleys, physiographic evidence of water action and vegetational evidence of its absence are, in a region of intense heat, inevitable.

This division of the annual precipitation into two periods would

result in marked diversity in the water relations of the plant species, even if the entire amount sank uniformly into the soil. Besides this fundamental source of diversity, there are others.

The amount of water which may fall in each of the two periods, and, indeed, during the whole year, shows great annual variation. The winter and spring showers may be very local. There are not only con-

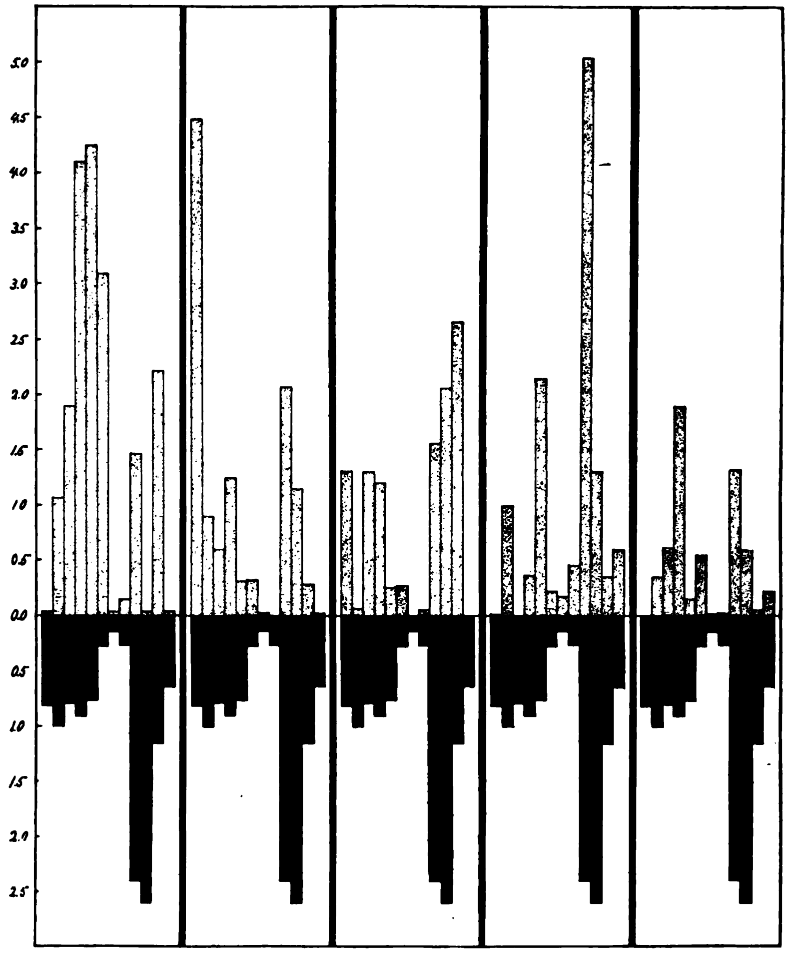

FIG. 1. In this figure are shown the monthly precipitation for five individual periods each of a biological year, beginning with November and ending with October. The rains falling in November and subsequent winter months are chiefly of significance in the development of the winter or spring annuals and in replenishing the reserve of the cacti. The rains falling in October may complete the development of the plants of the second, midsummer, period of growth.

Note that there is not only a division into two distinct rainy seasons which recur annually, but that there is great variation in the amount and time of rainfall from year to year.

The dark area is the average for fifteen years as given by MacDougal. It is repeated under each year to show the extent of variation from the average.

spicuous differences from year to year, but in the same year tracts, only a few hours' ride apart, vary greatly in the state of development of their vegetation.

The soil moisture of a region so variable in rainfall and so diverse in surface topography and in depth and texture (and consequently in water-absorbing power and retaining capacity) as the environs of Tucson, presents a problem of great complexity, even if one considers it from the physical side alone, and not in its more complicated relation to the plant organism.

One must remember that the water which is of service to the plant is not the amount recorded by the rain gauge. Only a portion of the water, falling upon a given spot, may become soil moisture for the plants which grow there. Besides the loss through superficial run off already indicated, there is unquestionably a sub-surface drainage which, when there is sufficient precipitation to bring it about, tends to irrigate some spots at the expense of others. In consequence, there is great variation in soil moisture in habitats otherwise apparently uniform.

By no means all of the water which sinks into the soil can be used. In the development of every plant organism there is a time factor. While physiological processes are carried through with great rapidity in desert plants, there is a minimum beyond which this time element can not be reduced. *Duration* of soil moisture, not merely *absolute amount,* is of great importance.

With regard to the permanence of soil moisture, the various habitats differ widely. Cannon has found that the upper levels of the soil of the bajadas were air dry at the end of three weeks after the rains, while those of Tumamoc Hill and of the Santa Cruz flood plain remained moist for a period exceeding six weeks. On Tumamoc Hill, the superficial soil layer may be so thoroughly baked during the dry fore-summer that the water content falls to about 2 per cent. of its volume; but beneath, the water supply is probably adequate for the growth of the more hardy and deeper-rooted shrubs, throughout the periods when other conditions are favorable. Anomalous as it may seem, the great evaporating power of the air is the cause of the retention of the considerable quantities of moisture in the lower layers of the soil—at a depth available to many perennials and in amounts sufficient for life and even growth during dry seasons. From the surface layers, evaporation is so rapid after a rain that a dry mulch is formed, preventing more or less effectively the loss of water from beneath.

Temperature shows not merely a fluctuation of over 100 degrees Fahrenheit during the year, *all falling above zero,* but great diurnal variation as well. In the growing and even flowering season of the winter annuals, the days are warm—or hot, in the terminology of the more temperate regions,—while the nights have freezing temperature.

A skim of ice may form over one's aluminum drinking cup at breakfast before he breaks camp to collect the earliest flowering winter annuals.

Topographic irregularities greatly complicate temperature relationships. Southern species may have their northernmost limits of distribution on the southwestern slopes of the rocky hills. Here the tem-

FIG. 2. Northeasternmost limit of the Organ Cactus, or Pitahaya, in a protected valley of the Cababi Hills about seventy-five miles southwest of Tucson, opening towards the Mexican desert. Here it is growing among the columnar giant cacti and a thick stand of half shrubs which are characteristic of the rocky slopes.

perature is far higher than over the crests where cold winds sweep against their northern slopes. It is in such localities that the splendid organ cactus, or pitahaya, flourishes, apparently beyond its reproductive limits, in the Cababi hills.

It is in these deserts that the temperature environments, which one might predict, from commonly accepted rules, are apt to be modified by the phenomenon which MacDougal has designated as Cold Air Drainage. During the night the air from higher levels, becoming cooled, flows down the rocky slopes through the canyons, where it may form true aereal rivers, and into the valleys where it lowers the night temperatures of the plant organisms.

The naturalist, trained in a region where there is not a great diurnal heating of the earth's surface and a rapid nocturnal radiation of heat from a rocky dry soil, relatively unprotected by vegetation, is apt to think of this factor as one that might be demonstrated to exist only by long series of exact instrumental observations. On the contrary, the phenomenon is readily appreciable. A beautiful demonstration is to be seen from Tumamoc Hill. In the early morning, the broad valley of the Santa Cruz seems filled with fog. This is really the mesquite smoke of Tucson carried down by the cold air drainage from the higher-

lying plains towards the Gila Valley to the northwest. Above the village, the smoke curls high and irregular; below, it is drawn into the cold air current and borne down the valley in a stream whose upper limits seem marked off along the bajadas of the Santa Catalinas with almost the linearity of the draftsman's T-square.

Shreve has shown that the temperatures in the valley may, in consequence of this factor, be many degrees below those of the hill.

When the temperature becomes sufficiently high—although absolutely it is very low—for the germination of the winter annuals the soil is apt to contain a moderate amount of moisture, at a little distance below the surface, but remains always at a relatively low temperature. Thus, although the soil surface and the sub-aereal parts of the plant (the stems and leaves) may be exposed to rather intense heat during the day, the more deeply penetrating roots are subjected continuously to the retarding influence of low temperature, while the shoots must carry on their physiological activities under the influence of alternating high and low temperatures.

The summer annuals, on the other hand, germinate after the rains have not only soaked but cooled the superficial layers of a substratum which has been both dried and heated to a great depth by the intense insolation of the fore-summer. Thus, their roots develop under conditions of favorable temperature at least, and generally of both temperature and moisture. The summer rains cool the air and change the atmosphere conditions from those of intense heat and enormous evaporating power to those of high relative humidity. Thus there is a brief period of optimum conditions for the luxuriant growth of plants with extensive leaf development. Relative humidity may range from 10 per cent. to saturation. In its relation to the evaporating power of the air and consequently to transpiration, variation in relative humidity is a factor of fundamental biological significance.

Such, briefly, are the salient physical features of the region. It is evident that the plants which inhabit it must derive their water from rainfall, not only meager in quantity, but irregular in local and temporal distribution, and which fails, to a great and highly variable extent, to penetrate into the substratum. This moisture they must draw from a soil irregular in depth and texture and in water-holding capacity and sometimes highly impregnated by mineral salts. Saturation of the soil for brief periods is followed by a condition of complete dryness in most localities. In others, deep-rooted species may obtain water throughout the year. All their physiological processes must be carried out under widely ranging temperatures. Their aereal shoots are exposed to intense insolation in an atmosphere which is generally dry, and often moving at a considerable velocity. Brief periods of high relative humidity may alternate with those of excessive evaporating power of the air.

Thus in every factor there is conspicuous environmental heterogeneity or variability. What are the consequences for living organisms?

First of all, the distribution of the rainfall in two seasons separated by a period of intense heat and dryness, in a region affording sufficient temperature for growth throughout the greater part of the year, results in two distinct vegetative seasons. The first is the period of winter and spring annuals, shrubby or frutescent perennials. The second is that of summer annuals and frutescent and arborescent perennials.

The annuals developing in the winter and spring months and those appearing after the torrential rains during the heat of July and August are not only subjected to widely different conditions of growth, but are specifically distinct and physiologically dissimilar. The life cycle of these winter annuals may be short or long, depending upon the distribution of temperature. They may germinate and begin growth with November rains and mark time in development throughout the colder winter months, and complete vegetation and fruition with the precipitation of February and March and the warmth of March and April. On the other hand, germination and initial growth may be delayed by low temperature and inadequate moisture until well into March, when, if water is scarce and temperature high, the whole life cycle of the plant may be of remarkable brevity. Under these circumstances, many of the plants open their flowers and even nearly or quite mature their fruits with the cotyledons still apparently functional.

If the winter rains be supplemented by heavy spring showers, the winter annuals, which would otherwise be dwarfed, except in the most favored spots, may show long-continued growth and attain a large size.

While the winter and summer annuals pass the periods of greatest extremes of temperature and of dryness in the form of resistant seeds, the woody perennials must remain exposed to the most extreme conditions of the year. In their physiological activities, they show the greatest diversity. Some respond to the winter moisture and spring warmth by foliation and fruition. Others lie dormant throughout the first growing season to burst into leaf and flower after the heavy summer rains. Some are physiologically active in one growing season only, others in both. *Fouquieria* loses its tender leaves whenever the soil becomes too dry, and clothes itself with green again, whenever temperature and soil moisture are favorable. *Mortonia* retains its tough leaves for years.

The second consequence of the division of the rainfall into two seasons, instead of one period of precipitation, usually found in desert regions, is a fairly luxuriant growth of tree-like perennials, as well as of small rapidly maturing annuals. Thus, these southwestern deserts have fittingly been called arboreal deserts; the greenest of all deserts.

It is this covering of trees, often mere shrubs, if size be the criterion

FIG. 3. Spreading arborescent cactus, *Opuntia* sp. growing near Hayes's Well, about forty miles southwest of Tucson. Mesquite trees in the background. The grass in the foreground is unusually abundant. Photograph by Dr. MacDougal.

of classification, but trees, properly so called, if age be taken into account, which takes away the monotony of the stones, gravel and adobe, only to replace it for the average traveler by a monotony of cacti, yuccas and agaves, scattered shrubby bushes or small trees—for the smaller plants are seen only at limited seasons of the year and are commonly not visible from the Pullman window.

FIG. 4. Young giant cacti or Sahuaros growing among spinose ligneous plants. Note the more mature giant cacti and mesquite trees in the background and the smaller shrubs and the procumbent platyopuntas in the foreground where the mesa floor is bare of most other vegetation. Photograph by Dr. MacDougal.

But the subjective monotony of the traveler has no objective reality in the paucity of conspicuous forms. Among the cacti, there are the generally procumbent flat-stemmed opuntias, or prickly pears, the shrub or tree-like round-stemmed opuntias, *Cylindropuntias,* or *chollas,* the barrel cacti, or bisnagas and above all the splendid fluted columns of the giant cactus or *sahuaro.* The latter is represented by but a single species, but there are five or six quite distinct and highly interesting round-stemmed cacti that are indifferently called *chollas* and a score of species of prickly pears and other cacti that can not be distinguished from a distance. When leafless, two acacias will not be distinguished by the novice from the mesquite belonging to quite a different genus. Add to these the palo verde, the ocatillo, the yuccas and agaves, *Dasylirion,* the omnipresent creosote bush and several other shrubs, which are less dominant in the facies of the vegetation: a respectable beginning, then, has been made upon a rather thick flora of the region.

In fact, the flora is not at all meager. The paucity of species is only apparent; it arises from the facts that only the more conspicuous ones are seen at all by the average tourist, that things which are quite distinct are liable to be confused, that those which do occur together in the same plant association are not all in a vegetative condition, and hence not easily distinguished by the novice, at the same time.

Standing as it does in a transition zone between the highlands of New Mexico and of northern and eastern Arizona and the great desert that stretches away southwest to the Colorado delta, with the valley of the Santa Cruz connecting it with the Sonoran Highlands on the south, with the diversity in environmental conditions which accompany a range of elevation of several thousands of feet within a radius of but a relatively few miles, it is inevitable that this region would exhibit a marvelous commingling of taxonomically and floristically diverse plant organisms.

The bare statement that the region contains a flora rich in genera and species and of diverse geographic origin or affinity is entirely inadequate as a description of its real biological diversity. The plants which one sees are of the most highly contrasted structural types.

Some few species have roots extending far down to a permanent water supply, in the few places where this is possible, others have a spreading underground system lying immediately beneath the surface. Growing side by side, one may see large bisnagas or magnificent sahuaros, whose stems contain hundreds or thousands of liters of water and hard dry-stemmed shrubs. During the brief moist seasons, plants with leaves as tender as those of our eastern forests hasten through their development in the shade of tiny-leaved trees, many of which, notwithstanding their small size, were old before the Spanish came down through the valley of

the Santa Cruz. Rooted in the same soil, one may find species whose juice shows high and others whose cell sap shows low concentrations.

Thus diversity or differentiation in the living organisms is not structural merely. After a few weeks in the field, the observer will realize, more fully than he has ever before, that the distinctions between species are not solely of the kind that can be drawn or photographed or ascertained by inspection of that sacred and indispensable mummy, the type specimen. The species of plants are not merely externally dissimilar, but inherently very diverse; they are not merely morphologically differentiated but physiologically very distinct; they are to be distinguished not merely by their external form, but by their methods of reaction to the various factors of their environment.

In the greatest variety of ways these morphological and physiological differences are exhibited. Many of these have been briefly indicated in foregoing paragraphs. To enumerate in greater detail, the diverse modifications of the structural elements of which the flowering plant is typically built up or the variety of response to environmental factors would carry us too far into technical descriptions.

It is this great complexity of environment and this diversity of organisms which render the southwestern desert one of the most fascinating and profitable of all regions to the biologist, whether by specialization taxonomist, morphologist, physiologist or evolutionist.

THE INFLUENCE OF GREECE ON SCIENCE AND MEDICINE

BY PROFESSOR D. FRASER HARRIS, M.D., D.Sc.
DALHOUSIE UNIVERSITY

IT may be said without inaccuracy that in ancient Greeee we find either the beginnings or the indications of every phase of intellectual activity characteristic of our present civilization, not excepting either the study of science or the practise of medicine. Were one of the Greeks of the age of Archimedes to appear to-day in the midst of our university activities, he would be surprised not at our study of philosophy or logic, or ethics, or mathematics, or languages, but at the state of those applied sciences which deal quantitatively with the various forms of natural energy. That we can measure the force of gravitation, or the rate of transference of heat or the quantity of heat transferred, that we employ the expansive force of steam, or the differences of electrical potential in order to make things move—these would indeed amaze him. Aristotle, for instance, would be dumfounded to be told that an egg could be hatched by the artificial heat of an incubator, for he taught that there was a very great difference between heat of physical and of animal origin; in fact, that they were absolutely distinct in their essence.

That one might contemplate natural happenings and distinguish their essence from their accidents, the Greek mind could comprehend; but what is so entirely modern is the way in which we have liberated and utilized the natural forces and incarnated energy, harnessed force to matter, and made energy manifest by transmuting one form of it into some other.

Man's muscles are of so much less account to-day than any ancient Greek would have dreamed it possible.

The Greek contributions to the science of mathematics are matters of common knowledge: almost every one knows that Euclid is the name of a mathematician and not of a subject; although we have heard of a schoolboy who, on being shown a bust of Euclid, asked, "Why didn't they have one of good old Algebra too?" The Greek did what he could—and it must be confessed very successfully—to study the properties of space, since it was denied him to investigate the forces operating in that space. He developed the science of pure spatial relationships; and although the name of Euclid is the best known of the geometers, it is far from being the only one. The Pythagoreans had investigated dimensions and quantities; Apollonius of Perga, conic sections, Archimedes mechanics, Heron hydrostatics, Diophantus arithmetic and al-

gebra; Eudoxus and Hipparchus, astronomy. Grecian architecture was the outcome of scientific principles just as much as of the perception of the beautiful. The columns of the temples were so constructed as to appear from the ground correct in outline and perspective, although in many cases they were neither vertical nor were their sides parallel. Euclid gives a full treatment of the mathematical principles of stereoscopic vision, as also does Galen.

If science is knowledge based on or flowing from exact thinking, the Greeks possessed such science, and laid down for all succeeding generations the philosophical basis for the superstructure.

There were natural philosophers as distinguished from metaphysicians from the earliest times. Aristotle and his pupils subsidized by Alexander the Great made vast collections of facts as truly empirical as those of any laborious collector or systematist of the present day. This spade-work in science was certainly less congenial to the Grecian mind than speculation; but some one had to do the spade-work and even that was not shirked. To the Greek mind the mere specialist or technician would have been deemed a monstrosity or a barbarian. To a person to-day who had acquired the facts of chemistry, let us say, without a knowledge of logic, mathematics, metaphysics, music, astronomy and modern languages, the Greeks would never have given the name of "scientist."

The Greeks cultivated the objective sciences with conspicuous success; they gathered facts in astronomy, optics, geography, zoology, embryology, botany and medicine, in very much the same general way that we do now. Without instruments of precision, they observed so precisely as to predict eclipses successfully. The universe, the environment, was to the Greeks a constant source of interest and of material for analysis; and this study of nature did not in the least impair their contemplation of the beautiful, the powerful, the graceful or the symmetrical.

But when we say "the Greeks," we do not confine our attention to thinkers within the geographical confines of Greece itself, we must include such seats of intellectual activity as her colonies at Pergamos and at Alexandria. Euclid, who left a certain portion of mathematics so complete that nothing was added to it until the seventeenth century A.D., was a resident in Alexandria and he flourished in the reign of Ptolemy I., King of Egypt (Ptolemy Soter who reigned from 323 to 285 B.C.). Euclid, who may have been born about 300 B.C., was one of the chief ornaments of that learned society at Alexandria which one, nowadays, would call a university, for it included philosophers, astronomers, mathematicians, physicians and anatomists. Not, of course, that Euclid really was the author of all the books extant and lost which have been attributed to him; for Proposition 47 of the First Book (In every

right-angled triangle, the square on the hypotenuse is equal to the sum of the squares on the other sides) was the discovery of Pythagoras; while Theon of Alexandria is known to have added certain definitions on his own account.

But even when we deduct all those portions of Grecian geometry declared by scholars to be earlier or later than Euclid, we are left paralyzed in admiration of the mind of the one man who was author of what is left.

We have no details of the life of Euclid; only one of his sayings has come down to us. When Ptolemy asked him if a person could not understand geometry without reading all his books—an enquiry with which many school boys in all ages have been in the deepest sympathy—Euclid replied: "There are no royal roads to geometry," alluding to those straight roads in Persia which were reserved for the king alone to travel over.

After Euclid, probably the next best known Greek mathematician is Archimedes, who in his youth studied at the Alexandrian School. Unquestionably the most original of the Greeks, Archimedes invented appliances and enunciated principles which remain of the utmost utility at the present day. The endless or Archimedean screw, although not now used for the purpose for which it was originally devised (raising water from the hold of a ship), is the parent of such diverse mechanisms as screw-nails and the steam-turbine. Archimedes made the first planetarium. His "Eureka" on discovering a method to detect alloy in the gold crown of Hiero of Syracuse, has become a hackneyed phrase. While we need not believe all that was told of him, of his engines for prolonging the siege of Syracuse, of the mirrors with which he set fire to the ships of the Roman fleet, etc., yet we may freely admit Archimedes to have been a mathematician and engineer of the first rank. The Archimedean principle of flotation underlies the possibility of things heavier than water floating in water. One of the sayings of Archimedes is in praise of the lever, a mode of the application of force which we have good reason to believe was known to the Egyptians long before Greece was civilized. Archimedes wrote, or to his inspiration are attributed, quite a number of books on pure mathematics, both of surfaces and solids, one of them, a treatise on the center of inertia, being of practical value at the present day. This book is regarded as the foundation of the theory of mechanics and it is a great advance on what Aristotle wrote on the same subject. By his own desire, the figure of a sphere within a cylinder was engraved on his tomb, for it was the relationship of these which Archimedes considered his greatest discovery. Archimedes was killed by a Roman soldier on the fall of Syracuse in 212 B.C. Cicero in 75 B.C. found the tomb overgrown with vegetation. Hero of Alexandria in his "Pneumatica" describes at least two devices

where either hot air or steam was made to do mechanical work. The one is a primitive type of steam-turbine, the other is the prototype of a class of engine which only after many centuries became practically useful.

Probably astronomy of all the objective sciences was that which the Greeks cultivated most successfully. This is not the occasion on which to relate even in epitomized form the evolution of astronomical knowledge among the ancients. From Thales of Miletus, who lived about 600 years B.C., to Ptolemy who flourished at Alexandria, about the 130th year of our own era, the knowledge of the behavior of the heavenly bodies had become increasingly more exact. Thales predicted an eclipse which "came off," if we may apply so irreverent a phrase to such event, on May 25, 585 B.C. Not that Ptolemy was the greatest, because one of the latest, of the Grecian astronomers. The discoveries of Hipparchus of Rhodes, in the opinion of modern astronomers are much more important. Not only was the observation of the eccentricity of the lunar orbit made by Hipparchus, but his observations on the motions of the moon became the data which enabled Dr. Halley in the eighteenth century to apply a most delicate test—the acceleration of the mean lunar motion—to Newton's great law of universal gravitation.

But the astronomical system of Pythagoras was actually nearer to the truth than was the Ptolemaic, for, for one thing, it made day and night depend upon the earth's rotation. He postulated a proper motion for the earth, and was thus more correct than Ptolemy. The system of Copernicus was more similar to the earlier than to the later Greek view; and, indeed, it was one of the charges brought by the church against Copernicus that his system was heathen and "Pythagorean." Anaximander made the first map of the heavens.

While we cannot speak of the science of chemistry as having existed in classical ages, since by "chemistry" we mean nothing earlier than the time of Van Helmont, yet every one knows that the Greeks speculated on the ultimate constitution of matter and on the substance of the universe with as much zest as they did on the constitution and nature of mind. The concept of the atom is purely Greek. Doubtless Dalton meant by "atom" something much more definite than did Leucippus or Democritus; but we cannot admit that Dalton's conception of the ultimate structure of matter was, as an intellectual analysis, any more subtle than that other which was the earlier by two thousand years.

Both Thales and Anaximander spoke of a universally distributed, primitive world-stuff, whether moisture, caloric, ether, was not determined, some one thing eternally abiding although its forms were many and evanescent. This does not differ essentially from the modern conception of the all-pervading ether whose properties underlie the forms of grosser matter.

The notion that matter could be, at least in thought, analyzed down to ultimate atoms, that is, bodies incapable of being further divided, was in no wise due to Dalton, but was adopted by him as the only reasonable hypothesis of the ultimate constitution of matter. Democritus further assumed that the atoms, rotating as they were imagined to do, must collide with one another, as a result of which certain properties of matter were established. This is virtually none other than the modern "kinetic theory of gases."

To Aristotle the inherent motion of the atoms was a difficulty; but this is a difficulty only to one who assumes that rest is more primitive, more of the original state, than motion. Our latest view is the early Grecian—that everything is in motion, and nothing is at rest, that rest is a relationship, the illusory result of movements in opposite directions.

That substance is infinitely extended and is primally one, that it is possessed of inherent motion, are Greek conceptions which though modified by centuries of subsequent thinking, are still of the warp and woof of modern physico-chemical working ideas.

Parmenides wrote on the oneness of substance, and was thence led in the sphere of religion to Pantheism.

It is admitted that Pythagoras and his school founded the science of mathematics and indeed gave the very *name* to the study. The Pythagoreans raised geometry to a pure science, severing it from its earlier association with the means of measuring actual distances on the earth's surface (mensuration). The Pythagoreans instituted the quadrivium or fourfold way to knowledge—the study of logic, rhetoric, geometry and astronomy—which lasted until the close of the middle ages and was always contrasted with the trivium or junior course of grammar, arithmetic and music. It is really to Pythagoras that the retaining of geometry and mathematics as a compulsory subject in all higher education is due; and we are sure that he has been thoroughly cursed by many generations of classically-minded but mathematically-incompetent aspirants after the degree of Artium Magister.

Pythagoras is also responsible for all the curious fancies about numbers such as, the odd and even, lucky or unlucky, right and left, dark and light, the good and evil numbers. He even attributed sex to numbers; three was male and two female, therefore five symbolized marriage.

These ideas linger on to this day: I have heard people tell me that if there were 7 of a thing, all must be well, since 7 is a "perfect number"; and I am repeatedly informed that some number or other is unlucky. The theory of numbers was of course illustrated in the 7 planets—the heavenly heptachord, which, being perfect, could not do otherwise than make "the music of the spheres." Pythagoras, however, did discover the objective vibrational relationships between the various tones in an octave.

Possibly Pythagoras is best known to people generally as the originator of the doctrine of metempsychosis, the transmigration of souls. To do penance for sins, the soul of a man might have to inhabit the body of a lower animal, *i.e.*, undergo a lower reincarnation. You remember when Malvolio is in prison[1] the clown, disguised as a priest, asks him:

C. What is the opinion of Pythagoras concerning wild-fowl?
M. That the soul of our grandam might haply inhabit a bird.
C. What thinkest thou of his opinion?
M. I think nobly of the soul, and in no way approve his opinion.
C. Fare thee well, remain thou still in darkness; thou shalt hold the opinion of Pythagoras ere I will allow of thy wits and fear to kill a woodcock lest thou dispossess the soul of thy grandam.

So that the origin of this joking was, by Shakespeare's day, already 2,000 years old.

The writings of Aristotle which deal with zoology and embryology are so well known that they need only be mentioned at this time. Of course it would be easy to show in how many things he was mistaken in regard to animal structure and function, nevertheless he was the first systematic student of zoology.

Long before Aristotle's time, however, Thales (639–544 B.C.) had speculated that all kinds of life, animal and vegetable, were derived from some one, common, living substance, thus anticipating our conception of protoplasm by about twenty-three centuries.

Empedocles of Agrigentum (504–443) wrote on the development of the fetus, and gave us the terms amnion and chorion which are in use at the present day. Anaxagoras had pondered on the power which the various organs of the body have of absorbing different forms of nourishment from the common blood. It is an unsolved problem yet.

No doubt there was the practise of the healing art before Hippocrates, just as there were poets before Homer. A learned German has collected all the allusions to physicians or the healing art in Greek poetry before the time of Hippocrates. It appears that such medical knowledge as existed before Homer was all of Egyptian origin. Homer mentions bones, sinews and intestines. He alludes to wounds and to the activities of surgeons with the army in the Troad, but never mentions internal diseases. He speaks of a woman Agamede who knew of all the healing herbs, and of Helen giving Telemachus nepenthe or the drink of oblivion. The onion, honey and wine are mentioned as drugs; and the bath followed by inunction as a therapeutic measure. Homer names two medical men, Machaon and Podalirius, sons of Asclepios, an unrivalled physician. Of the former he said:

A wise physician skilled our wounds to heal
Is more than armies to the public weal.

[1] "Twelfth Night," Act IV., Sc. II.

That Xenophon, for example, recommended black as a restorative in cases of snow-blindness, does not entitle us to suppose that therefore Xenophon had any medical knowledge.

Hippocrates the Great was certainly the first in Greece to commit to writing a body of knowledge dealing with the diagnosis, treatment and prognosis of disease.

It is usual to trace the origin of Greek medicine to the worship of Asclepios (Latiné, Æsculapius) the God of Healing, son of Apollo. The cult of Asclepios was certainly very old and probably modelled on Egyptian lines. Sick people were brought to the temples of Asclepios just as to-day in Roman Catholic countries invalids are brought to shrines, or in all countries to spas or watering-places.

The priests of Asclepios or the Asclepiadae were not physicians so much as men who mingled with their religious activities a considerable amount of common-sense regarding the therapeutic power of mental suggestion. Hippocrates, who was not an Asclepiad but the chief personage at the medical school of the island of Cos, belongs to the age of Pericles. It is proper that in the golden age of Greece's history, the Father of Medicine should have arisen. He is supposed to have been the son of Heraclides, an Asclepiad, and the midwife Phænarete, and to have been born about 460 B.C.

The deservedly great fame of Hippocrates rests on his insistence that disease is a natural phenomenon, not some visitation of supernatural origin. He studies the sick man as a whole, entirely in the modern spirit, recognizing that we must observe closely in order first to learn the facts of the ailment, obtaining the natural history of the disease, and must recognize all the time that nature is in the main striving towards the recovery of the health. Of course some previous theoretical guidance was assumed necessary, but Hippocrates came each day to a case like an unbiased natural philosopher approaching some problem new to him.

In its Latin dress of vix medicatrix Naturæ, the healing tendency of living matter is familiar to most of us. A great deal of the so-called Hippocratic writings are not from the hand of Hippocrates, many being later than his time; but enough that are genuine remain to convince us how high were the ideals of Hippocrates in the sphere of morals, no less than in that of medicine. The oath of Hippocrates is a noble document. Whether it was composed by Hippocrates himself may be doubted, but it accurately represents the high aims that Hippocrates had before him in his practise. Composed as it was in times long pre-Christian, it is to-day as worthy a guide for the conduct of the physician as can be found in any literature; and its obligation to keep professional secrets may well be pondered over by those members of our profession, who, in neglecting this part of the oath, are guilty of a grave offence against

the ethics of their calling. I need hardly say that the "Aphorisms of Hippocrates" have long ago taken their place immovably amongst the world's classics.

Many more doctrines in medicine are due to Hippocrates than most people, even most physicians, believe. The doctrine of humors, of the healing power of nature, of critical days (this latter the result of Pythagorean influence), are all Hippocratic; while "Hippocratic succession" and the "facies Hippocratica" have been an integral part of medical terminology for 2,300 years. Hippocrates recognized four humors, blood, phlegm, yellow bile and black bile, a proper or due mixing of which constituted good health, an undue predominance of any one, disease, notions which gave rise to the "humoral pathology" which dominated medicine for ages, and which in another sense dominates it still. Hippocrates, as one might suppose, had a much better knowledge of the bodily organs than of their functions. He certainly confused nerves, tendons and ligaments, a mistake quite excusable, seeing that they are all very similar in the dead body of a lower animal; for there is no evidence that Hippocrates examined the body of any animal during its life. In all probability he did not even dissect the human body. The bare idea of doing so would have been repugnant to the beauty-loving Greek. Some of the Hippocratic physiology is not far from the truth, some of it far indeed. He knew that food was "cooked" in the stomach, that a lesion on one side of the brain produces paralysis on the opposite side of the body, that the heart contains blood, that the liver prepares blood and bile, and that the lens of the eye has to do with vision. He knew that local fatigue could, if sufficiently developed, produce general fatigue. Hippocrates divided diseases into chronic and acute, endemic and epidemic, distinctions we recognize yet.

Again the terms angina, catharsis, catarrh, enema, paracentesis, glaucoma, gangrene, syncope, hemorrhage, "healing by the first intention," are all terms of Hippocratic medicine in use to-day. The Father of Medicine wrote on the principles of surgery, obstetrics, dietetics and treatment. As regards treatment he was thoroughly eclectic, using every means in his power to restore the sick man to health. The modern treatment of fevers is essentially Hippocratic; febrile patients were allowed to drink water or barley water; later medicine, arriving at the doctrine that water was injurious to the fevered organism, practised much unconscious cruelty and undoubtedly sacrificed many lives.

Hippocrates is the all-round physician; he knows all that has gone before in his science. "The physician," he says, "must know what his predecessors have known if he does not wish to deceive both himself and others." He studies everything concerning his patient, his heredity, the objective signs, and the subjective when he can elicit them. His profession is to him as art to the artist: "Where is love for art, there

is also love for man." Hippocrates is the good physician, at the very ethical antipodes from the quack or mere drug-prescriber. His is the large, sympathetic, wise, tactful, kindly outlook not so much towards disease as the diseased man; he is the exponent of the highest Greek culture in the realm of applied medicine. Although the schools of Cos and of Cnidos continued for a long time to exert their influence, with Hippocrates and Pericles passed away the brightest hour of Greece's glory at least in matters medical. The succeeding century was comparatively sterile as regards contributions to practical medicine.

For although Plato wrote on certain matters belonging, as we should now think, to medical science, his influence built up the school of the Dogmatists whose chief tenet was that reflection should come before experience. In fact, philosophizing about disease rather than the observing of patients became the vogue in some quarters, so that much post-Hippocratic medicine is clinically barren. It may be doubted whether Plato understood more perfectly than Hippocrates any bodily function, save perhaps the respiration. Plato's doctrine of the soul as a separate existence, residing in the "marrow" (presumably the central nervous system, not the bone-marrow), concerns us here only in so far as we see specified one of the earliest seats of the soul and that a neural one. Chrysippus of Cnidos (born B.C. 340) regarded the soul as being in the blood, on which account he would not employ venesection, but did use tourniquets on bleeding limbs. Both Pythagoras and the Egyptians had taught that the soul was in the blood, a view consonant with that in the Old Testament, "for the blood is the life." According to Professor Ostwald, Plato is responsible for all the difficulty in connection with the problem of the relationship of mind to matter. His words are:

> Through the age-long effect of the blunder committed by Plato in making a fundamental distinction between mental life and physical life, we experience the utmost difficulty in habituating ourselves to the thought of the regular connection between the simplest physiological and the highest intellectual acts.

Praxagoras of Cos was the teacher of Herophilus, himself one of the best known teachers of that important school of medicine or university at Alexandria which was founded by Ptolemy Soter and continued to be a source of Hellenic illumination as late as the second century of our own era.

Praxagoras it was who, first distinguishing arteries from veins, taught that in health the arteries did not contain blood, but that, as blood always flowed from them in wounds, they must have taken it up from the flesh round about.

The other famous name of the Alexandrian Museum was Erasistratus, whose teacher had been Metrodorus, the son-in-law of Aristotle. By the mention of that great name, probably the greatest of antiquity, we are introduced not only to the encyclopedist of Hellenic science, but to

an influence which exerted itself in ever increasing force almost to within our own day. For, as Professor Mahaffy says, the man whose writings dominated European thought in logic and in the mental and physical sciences for more than a millennium, and who came within a very little of being canonized by the church of Rome, was probably the greatest of the ancients. Aristotle was as much the creator of the science of logic as he was of the sciences of zoology, embryology and comparative anatomy. He discovered the heart of the unhatched chick (punctum saliens) and saw it pulsating. He named the great artery that proceeds from the heart, aorta, by which term it has ever since been known. He adopted the Hippocratic classification of the humors, but did not rectify the confusing of nerves with tendons. He distinguished arteries from veins; but he described a vein from the liver to the right arm, and another from the spleen to the left arm, hence blood letting on the same side as the organ affected was especially valuable. This error gave rise to a long controversy during the Middle Ages as to where to open a vein; entire medical schools, even whole universities, being ranged on one side and on the other.

To Aristotle the heart is the acropolis of the body, and he makes the neura or tendons arise from the heart. The nerves, as canals leading from the brain, he understands, but, believing the brain to be bloodless, he attributes no functions of any great importance to it. The object of respiration he imagined to be the drawing in of cold air to cool "the innate heat of the heart," a view which was held until the time of Harvey. As Professor Driesch says:

> What inspires us with the highest admiration of the great Greek thinker is the way in which he perpetually and manifestly struggles for clearness in this hardest of all Nature's problems (life).

Aristotle frequently writes with his eye on the medical profession. He says:

> It is the business of the naturalist to know also the causes of health and disease, hence most naturalists see in medicine the conclusion of their studies; and of physicians, those at least who display some scientific knowledge in the practise of their art, begin the study of medicine with the natural sciences,

so that custom at least is as old as the time of Aristotle.

But this is, indeed, a late date to be telling people what Aristotle did for every department of knowledge to which he had access. His writings were the academic text-books of the Middle Ages; and the study of them is by no means dispensed with at our seats of learning to-day.

From about 300 B.C. onwards for several hundreds of years, medicine flourished in particular in two Greek colonies, Alexandria in Egypt and Pergamos in Mysia. Both were populous and rich cities, centers of all manner of intellectual and artistic activities.

Alexandria beecame the seat of the most important university of antiquity: all the branches of study were represented there, and anatomy and medicine were taught with a thoroughness nowhere else attained except at Pergamos. To have studied at Alexandria was, as late as the end of the fourth century A.D., the highest recommendation a physician could give.

Herophilus of Chalcedon (335–280), who was physician to Ptolemy I. (323–284), and Erasistratus of Iulis, in later life physician to Ptolemy Philadelphus (284–246), may be regarded as the founders of the Alexandrian school of medicine. The views of these two leaders were not identical, so that in course of time two distinct lines of medical dogma became established, those of the Herophilists and of the Erasistratans, respectively.

The advances in medical knowledge made at Alexandria were due to the untrammelled study of practical human anatomy. Herophilus, it is said, went so far as to dissect living persons, criminals assigned to him by the authorities.

Herophilus left his impress on anatomy for all time: he discovered the meeting-place of the cerebral sinuses in the occipital region, naming it the torcular; he gave its name to the duodenum, he called the pulmonary artery the vena arteriosa, and the pulmonary vein, the arteria venosa. He correctly taught that the pulse is due to the heart's systole, and he knew that arteries contain blood. He described the liver, the oviducts, the hyoid bone and many details in the anatomy of the eye. Herophilus traced nerves to and from the central nervous system, and, describing the brain, gave to an appearance in the Fourth Ventricle the name of Calamus Scriptorius which it has ever since retained. Herophilus believed the soul resided in the Fourth Ventricle. Herophilus discovered the receptaculum chyli and certain large lymphatics which were rediscovered only in the seventeenth century. Erasistratus made even a more thorough study of the brain than did Herophilus, and attributed mental diseases to lesions of that organ or of the cerebellum. Though he denied that the arteries contain blood, Erasistratus wrote with insight on paralysis, dropsies, liver disease, digestion, absorption and treatment both by drugs and by surgery. Erasistratus is remembered for having diagnosed the cause of the illness of Antiochus, son of Seleucus Nicator, whose physician he was. Erasistratus discovered that the prince was in love with his stepmother, Stratonice, because of his blushing and palpitation whenever that lady entered the room. Erasistratus was evidently a physiologist. Whether or not it was with a view of curing Antiochus, I cannot say, but Erasistratus prescribed marriage with Stratonice, for which advice he received a fee of $100,000.

The following belonged to the school of Herophilus; Demetrius of Apamea (276 B.C.), Collimachus (246 B.C.), Zeuxis of Laodacea, Dio-

scorides (40 B.C.) the physician of Cleopatra, and Aristoxenes (A.D. 79). Demetrius of Bithynia and Heron of Alexandria are well known names in Alexandrine medicine. Heron, a mathematician and physicist as well as physician, was a contemporary of Archimedes; he described a water-organ, the invention of his teacher Ctesibius.

The other great school of medicine in a Grecian colony which alone rivalled Alexandria in learning and culture was Pergamos, that same Pergamos where "Satan's seat is," as it is expressed in the address to the Angel of the church at Pergamos. The library at Pergamos was almost as famous as that at Alexandria: when Ptolemy Soter would not allow the exportation of papyrus from Egypt, the Pergamites used animal skins for their books, hence "parchment."

The age-renowned Galen was a graduate of the school at Pergamos, and the names of his teachers in anatomy and pathology survive to this day. He studied anatomy also at Smyrna under one Pelops, and for some time at Alexandria under Heraclianus. It was here, he says, he had the good fortune to see a human skeleton.

Claudius Galenus (to give him his Latinized name) was a Greek, he wrote in Greek, and his works were not translated into Latin until the fifteenth century. Galen, the son of an architect Nicon, was born at Pergamos in A.D. 130 and died in Rome, it is believed, about the year 200. Nicon, having had a dream bearing on his son's future, devoted him to a study of philosophy and medicine from as early as his fifteenth year. On returniing from his travels to his native city when he was about 28 years old, Galen was appointed surgeon to the school of Gladiators at Pergamos. Six years later he went to Rome where he lectured on physiology and on medicine, it would appear, on Hippocratic lines. He does not seem to have had very amicable relations with his colleagues, so he left Rome for a time and returned to Pergamos. After about a year's absence, he was recalled by the Emperor Marcus Aurelius to whom he became physician. Declining to accompany his master on his military expedition against the Marcomanni, Galen remained in Rome as physician to the Emperor Commodus. Though Galen cetrainly extended the knowledge of both structure and function beyond Hippocratic limits, he corrected, unfortunately, but few of the worst Hippocratic mistakes. It is doubtful whether he ever dissected the human body, for, as Vesalius pointed out, his anatomical descriptions apply chiefly to the monkey and the pig. Hence he commits the serious anatomical error of placing the human heart in the mid-line instead of to the left of it. In physiology he went far beyond Hippocrates, probably because he dissected so many animal types, and certainly because he examined some of them while still alive. Galen was known in Rome as the "wonder worker," on account of his having cured Commodus of a very severe illness.

If Hippocrates is the Father of Medicine, and Aristotle the Father

of Embryology, then Galen is the Father of Experimental Physiology. For he discovered that certain nerves were motor to certain muscles of the back, that the inferior laryngeal nerve was the nerve of voice, that the spinal cord was the conductor of impulses necessary for sensation, and that those crossed from one side to the other in it. Galen recognized thirty pairs of spinal nerves and seven pairs of cranial; he knew of sensory fibers in the abdominal sympathetic, and of the vital importance of the medulla oblongata.

The Galenical doctrine of spirits—natural, animal, vital—dominated physiology for fourteen centuries. Galen corrects Aristotle in making the nerves proceed from the heart, but at the same time he denies that the heart has any nerves of its own. He still thinks that in breathing, air is drawn into the chest to cool the heat of the heart, but he recognizes that "sooty" matter escapes from the lungs; he believes that the liver forms blood from digested food.

Galen knew tears to be the secretion of a gland and not an escape of aqueous humor: he discovered the six pairs of muscles of the eyes, and the muscles of the larynx. It was he who first described the Tendo Achillis, which quite explains why it has a Greek name. Galen's view of structure was always physiological, hence the titles of his works—"De usu partium corporis humani," "De motu musculorum," "De morborum causis." It was on the vascular system that Galen had least light. No notion of a circulation occurred to him. He thought that blood conveyed by the veins to the tissues was there used up in nourishing them. Crude blood with animal spirits from the liver, he thought, passed to the heart where the vital spirits were originated; animal spirits being produced as a further result of a refining process when the arterial blood had reached the brain. "Spirits" are too firmly embedded in our language for us ever to get rid of them. Galen imagined that the blood of the great pulmonary artery went to nourish the substance of the lungs, a notion of which Harvey pointed out the inherent improbability. Galen did, however, discover that an artery has three coats. He insisted that blood passed from the right to the left side of the heart through pores in the septum: Vesalius ridiculed this assertion, Harvey disproved it.

Galen regarded the heart as the seat of courage and the liver of love, a doctrine of local situations for mental attributes which has hardly died out up to the present time. The conceptions of the phrenologists are merely a development of this sort of thing, very different, however, from what is known as the localization of cerebral function. The liver and love were associated as late as Shakespear's time, when Pistol avers that Falstaff loves "with liver burning hot."[2]

Galen is responsible for the well-known doctrine of the four temper-

[2] "Merry Wives," Act II., Sc. I.

aments, the choleric, melancholic, sanguine and lymphatic. He also first gave the so-called four cardinal signs of inflammation: heat, swelling, redness and pain (calor, tumor, rubor and dolor). It is interesting to know that inflammation is possible without any of these four being present. Galen is less of the clinician and more of the systematist than Hippocrates; he is more of the anatomist and physiologist and less of the physician. His writings are very voluminous, for, besides on medical subjects he wrote on philosophical, grammatical, mathematical and legal topics. Forty-eight medical works alone are lost.

There is in Dalhousie University a Latin translation of the works of Galen by a Spaniard, Andreas Lacuna or Laguna, published at Strassburg in 1604, which edition is not in the British Museum.

In a sense it is a fact, then, that all the conceptions which were the intellectual working ideas of the Middle Ages were given to us by the Greeks. The Romans contributed practically nothing to the body of knowledge called science or to that called medicine: Pliny tells us it was beneath the dignity of a Roman to be a physician. Action, not contemplation, was characteristic of the Roman temper.

The fundamental concepts in astronomy, geometry and arithmetic, the entire sciences of logic and ethics; the speculations that were metaphysical, the notion of species, of evolution and yet of the oneness of living matter, the doctrines of the indestructibility of matter, of energy as inherent in matter, of the ultimate atomic constitution of matter were all products of Greek thinking.

The mind of Hellas supplied the materials of thought for subsequent speculation; and in very truth it touched nothing which it did not adorn. From the Greeks we inherit mental subtlety and the analytical aspect of the intellect. The Middle Ages added surprisingly little to this mass of mental currency, though some of the Hellenic coins were sadly defaced by excessive handling. Christianity did indeed introduce certain conceptions far enough removed from anything that the classical ages had attained to, but these were chiefly in the sphere of morals; they were not in objective science. The thinkers of the Ages of Faith made it their concern to mix the philosophy of Plato and the metaphysics of Aristotle with as much of the teaching of the Nazarene as they felt inclined. But with this aspect of things we have no concern to-day, for in "science" I do not for our present purpose include theology. The Middle Ages added no conceptions in regard to the universe or to life as fundamental or as comprehensive as those they inherited from pre-christian times. There were, of course, workers like Albertus Magnus and Roger Bacon; but how little encouragement or approval the latter, at any rate, received from his ecclesiastical contemporaries is very well known. Until that awakening of the mind of man known as the Renaissance, not only had thinkers not added anything essential to the body of natural knowledge handed down from antiquity, but a very great deal that the ancients had taught was either distorted or totally forgot-

ten. I will, however, go much farther than that and say that in treatment, our profession up to as late as 100 years ago had forgotten a very deal of the practical therapeutic sanity of the Greeks, and had replaced it by a fantastic and revolting empiricism. The accounts of the doings of medical men at the death-beds of, *e.g.*, Charles the II. or Lord Byron are painful and humiliating, deserving of all the satire which a Molière could invent.

Vulgar representation and monkish credulity were soon mixed up with the few facts of medical learning which had survived the Fall of the Roman Empire. Astrological and alchemical verbiage obscured truths well known 300 years before Christ.

Hippocrates, Aristotle and Galen were not studied in the original, for the language of Greece was both dead and buried, but through Latin translations of Arabic translations. Not only did men not go back to Nature, they did not even go back to the authorities in their original tongues. Trifles of no medical or physiological importance were made the subjects of bitter debates that lasted through many generations.

It was the Arabian physicians who, through their translations of the Greek medical classics, preserved chiefly in Spain the learning of antiquity from suffering extinction during the earlier Middle Ages.

The grand objective simplicity of Hippocrates had given place to pseudo-philosophical and quasi-learned disquisitions about the principles of treatment. Certainly it is true that in every school of medicine the writings of Hippocrates and Galen were the text-books (as when in "The Merry Wives" Evans says, "He has no more knowledge in Hibbocrates and Galen," etc., and again "What says my Æsculapius? My Galen?") The lectures, in fact, consisted in readings from their works and discourses upon what was said therein. In course of time it became a heresy to discover an error in Galencial anatomy, a grave offence to propound a view of functional activity contrary to or beyond that indicated by the Pergamite. This intellectual bondage lasted until the middle of the sixteenth century, when by the boldness and industry of the Belgian Vesalius, and by the originality and candor of the English Harvey, the reformation of anatomy and physiology was accomplished. Vesalius' text-book and Harvey's discovery swept away forever the mental miasms of the Dark Ages. The error of the men of the Middle Ages was not that they revered too much the writings of the great ancients, but in holding that these were beyond criticism and contained the last words in matters medical. The writings of Galen they had allowed to become not merely a great text-book but a work of super-human authority. This was perhaps the greatest honor that the mediocre could pay to the master mind, and that mind the Hellenic. The golden gleam of the glory that was Greece failed not to light as with the kindly glow of a summer evening's sun the thousand years of those ages which, otherwise, would have been dark indeed.

IS A BALANCE OF TRADE IN FAVOR OF EXPORTS FAVORABLE?

By CHARLES A. GILCHRIST

BERKELEY, CALIF.

IMAGINE a country or any geographical area, the inhabitants of which trade freely with the rest of the world, but who in all other respects are sufficient unto themselves. That is to say, we suppose the inhabitants not to travel abroad and outsiders not to travel within, and that none of the resources of the country are owned without and that no outside resources are owned within. It is then evident that the imports of the country must be equal to the exports in point of value, that is, the imports are paid for with the exports. And of the actual international trade of the day we may say: "Other things being equal, any change in imports begets an equal change in exports."

Our inquiry divides itself conveniently into three parts. First we will examine this statement as it stands and see how the mechanism of modern trade tends to maintain a balance between imports and exports. We will then examine the gold question. Is it favorable that a country's imports should contain more gold than her exports? The third part of the discussion will consider those less visible factors in international trade which prevent the equality of imports and exports.

The truth of the statement we are first to examine is apparent on *a priori* grounds—value will be given only for value received. But the intermediate steps in the complicated mechanism of trade that brings it about are not so apparent. How, for example, can a new duty restricting imports into the United States also operate to restrict our exports? Supposing, for simplicity, that we are dealing only with Great Britain. Since we now take less from England, English merchants will have less paper demanding gold on the London exchange. A tendency for gold to flow from England to America is set up by the over-supply there, and manifests itself in the ability of American brokers to secure the metal at a discount. When this discount passes a point just sufficient to cover freight, insurance and interest during transit, gold will be shipped to America. Now the amount of gold for which a thing will exchange is its price—the dollar being by law the exchange value of 23.22 grains of gold. This influx of gold to a country with free gold coinage, and not coming into response to any other demand, will swell the currency and, conversely, prices in general will rise. Assuming that

our supposed curtailment of imports is permanent, gold would continue to flow until prices in general changed, on both sides of the water and in opposite directions. Thus prices will go up in America and down in Great Britain, and English merchants will buy less in America in favor of their own home market. Since their purchases in America are our exports, it follows that our export trade will fall off. Which is what we wished to show.

The change in the prices we have just shown can have no permanent effect upon the internal commerce of either country, for an equal change in the price of everything simultaneously is not a change in exchange values generally.[1] But as between nations, the change is in an opposite direction and very materially affects the international trade. It should be noted that although the change in imports is permanent, the flow of gold induced is not permanent. It is only an initial flow, just sufficient to change the stocks of gold in circulation in the nations in question, to the critical point where changed prices will affect exports in like amount. After that, gold will return to its normal rate of flow.

Of course such a chain of cause and effect could never be illustrated by the actual course of events, for the reason that the "other things" we have imagined equal never are equal. This tendency to a decrease in exports might be entirely neutralized by a counter tendency such, for instance, as a rise in rents of American real estate owned by Englishmen living in England. Economically speaking these rents go to England as commodities, exports, real goods—although the recipient receives not any specific goods so exported, but a draft for gold, which in its turn is merely a draft for so much of any kind of wealth the holder may choose to select from the whole English market. The credit instrument representing the rent due is the effective cause of the flow of just so much real wealth from American shores. International payments are made in goods—real wealth, imports and exports.

This mechanism of trade is purely automatic. It bears the same relation to society that the involuntary functions of the body, such as the circulation of the blood, bear to the individual. Since a country does not transact its foreign commerce in its corporate capacity as a nation, but only as the sum of the transactions of its individuals and commercial houses—a national debit and credit account can not be periodically drawn up to show the total of all transactions. But such an account exists in effect as the sum of the accounts forming its parts. For a single year, or some short period of time, such an account would show an outstanding item or balance representing transactions not yet closed, but this would always be in the act of liquidating itself and would

[1] From 1870 to 1897 there was a gradual fall of about 50 per cent. in prices generally, but by 1910 about half of this had been regained. ("Principles of Economics," H. R. Seager, page 377.)

not accrue with the passage of time. It is not the balance of trade we are here concerned with. In the discussion of the balance of trade as in the discussion of the business of an individual, we are interested in a debit and credit account only to the extent that it shows closed transactions, for only then does it show what is being done as a regular thing, or in the long run. Indeed, the "balance of trade" as a question of "policy" can have significance on no other ground.

It appears from the foregoing that the first effect of checking imports of commodities is to substitute imports of gold, but it has also appeared that the substitution is temporary and is entirely shifted to a permanent checking of exports. This is to say that a nation in its corporate capacity can not force traders to deal in gold—it can not create a demand for gold, and the truth of this will become more apparent as we go on. But our attention must now be turned to the permanent or normal flow of gold. Is a balance of exports regularly liquidated by gold favorable?

This is the gold question. Under the conditions we are supposing, the entire excess of exports would be regularly paid for with an equivalent of gold imported. The "mercantile system" of the eighteenth century regarded the nations as competitors for the world's gold, and each country endeavored to increase its stock of gold indefinitely by attempts to restrict its imports and expand its exports. This idea is now generally abandoned, and among the foremost nations no conscious attempt is now made to attract gold. Indeed, in the case of a country like the United States such an attempt would be without reason, since the United States produces nearly one fourth the world's supply of gold, and is therefore normally a gold-exporting country. Whatever tendency there may be for export balances to become liquidated in gold, it is apparent from the statistics of the foreign trade of the United States that, in our country at least, the persistent balance in favor of exports *is not* paid for in gold. In the last twenty-five years (1890 to 1914 inclusive) the yearly balance for gold has fluctuated between favoring import and favoring export, ten times, while the net balance for the whole period is an insignificant amount (21 millions) favoring gold *export*. For the same period our balance of general trade favoring exports has steadily increased (excepting only the year 1893) to a net amount over *four hundred times* greater than the gold balance (9,358 millions). For any single year the greatest balance favoring a gold import occurred in 1898 when we could truly say that one sixth of our balance of exports, at least, was paid for with gold. But the figures in general are highly incomparable, and the most they show us is that the United States is not the example we are looking for—an example where "other things" are equal. As far as the gold question goes, our thesis remains—is a balance of exports liquidated by gold favorable?

The answer to this question will be in two parts. First, that in so far as the movements in such an exchange are free, obeying the natural law of supply and demand and each commodity moving from a point of lesser value to a point of higher value, the fact of gold being a principle in the exchange can be counted as neither favorable nor unfavorable. Being free bargainers, both parties must benefit in such an exchange or no exchange could take place. The party that sends the gold is better off, as well as the party who gets the gold. Thus a free and healthy exportation of gold would result in a country from such causes as an extensive gold-mining industry, an inflation of the currency with an increasing use of credit money, or from a decreasing demand for jewelry. This free or natural movement of gold, then, forms no part of the "balance of trade" discussions for gold so moving simply takes a place along with all other commodities forming the international trade.

The second part of our answer refers to a movement of gold that is not free, that is to a movement consciously instigated by a nation acting through its government. It was such a movement the "mercantilists" believed the successful nations succeeded in bringing about, draining gold from the less successful nations to themselves, in spite of the strong tendency to a counter flow which such an unequal distribution of gold would induce. They believed such a nation was thrifty in that it was saving wealth in the form of stored gold, to be reexchanged in time of war or stress, for useful commodities from other countries. This idea was probably a survival from times when interest-earning capital wealth was little known.

It is necessary to keep clearly in mind that we are not now discussing the free or natural movement of gold. Gold acquired with intention to save is not for use in coinage or any other way, for that comes through a natural demand. Gold stored in vaults serves no present use, but only the potential use contingent upon war.[2] It is capital wealth out of use —not drawing interest. For a nation to store wealth in this way it must buy gold with its commodities from other nations, paying an ever increasing premium as the foreign supply diminishes. Whatever the enactment which brings this about, it is in essence a tax upon the coun-

[2] The mind of the reader may here revert to the gold stored in the United States Treasury as security for paper money in circulation. The money problem properly forms no part of our subject, but for the sake of keeping proper proportions in the mind it may be well to state what this store of gold is. According to the report of the Secretary of the Treasury, there were one thousand eight hundred and fifty-eight million dollars in circulation and in the treasury, in the form of gold coin and bars, on April 1, 1913. Fifty-eight per cent. of this was security for gold certificates in circulation. If our balance of exports for the last twenty-five years had been paid for in gold, the amount would have been sufficient to increase this government stock sixfold, making it about eighty per cent. of the world's stock of gold.

try's own people who furnish the commodities with which to pay. In a sense they are paying interest on a debt before it is incurred—the debt of war. The people are saving only in the sense in which a miser saves, only because they have a certain soreness and fear towards other peoples. It is a superstitious regard for gold that no longer exists. A nation that hoards gold is making a sacrifice for something in which other nations are not trying to forestall her. To-day the process of saving is a creation of working capital goods, of wealth such as buildings, railways, machinery and so on. And in time of war such working wealth is quite as negotiable as gold, for a country at war may not only sell her securities for the necessaries she may immediately need, but so stable has the commercial world become she may undertake a public debt by issuing bonds for sale to other nations. The hoarding of gold is bad then, because working capital is better than idle capital, even in time of stress. Since this is now generally recognized, the point in favor of hoarding can not be granted even as a concession to "relative ethics." The nations of to-day are hardly more keepers of gold than are our rich men.

Therefore we say: A balance of exports induced for the purpose of storing gold for time of stress is unfavorable. Indeed, it seems to be doubtful if in these times such a balance could exist, but that in general it does not exist is sufficient warrant for the elimination of the gold question from the trade controversy by merging gold along with other commodities making up exports and imports. Gold moves first only because it has the least bulk and weight for a given value, but this gives it no distinction in kind over pig iron or any other form of wealth. The discussion is now reduced to that net balance of trade remaining after gold has been accounted for by including it in the inventory along with all other commodities.

Having satisfied ourselves that international payments are made in goods, exports and imports, of which gold is only one out of several hundreds, we have cleared the ground for the third part of our discussion, for an examination of the causes that make a "balance of trade" possible.

An international debit and credit account is not complete until every transaction affecting the transfer of wealth has entered into it. On broad lines such transactions might be divided into four classes, which would include them all. These are: exchanges, gratuities, loans and interest. Wealth may pass between two parties through free exchange, free giving, free lending or giving through coercion. The term interest is made broad enough to include everything from interest strictly speaking to tribute pure and simple. If we expand this to embrace in a more concrete way the larger items of present-day trade, we are able to frame up a general debit and credit account of one country with the rest of the world which is typified by:

ACCOUNT OF THE UNITED STATES WITH FOREIGN COUNTRIES

Debit	*Credit*
1. Imports (including gold).	1. Exports (including gold).
2. Interests on American securities and loans held by foreigners.	2. Interest on foreign securities and loans held by Americans.
3. Purchase of foreign securities, and loans to foreigners, by Americans.	3. Purchase of American securities and loans to Americans by foreigners.
4. Expense of Americans traveling abroad.	4. Expense of foreigners traveling in America.
5. Use of foreign vessels.	6. Remittances to immigrants by friends left at home.
6. Remittances by immigrants to friends left at home.	

A "favorable balance of trade" is considered to be a balance in favor of exports, an excess of exports over imports. Contrary to the general opinion, we propose now to show that such a balance is in reality not favorable.

Since the debit side of our international account from the point of view of the United States must always be substantially equal to the credit side, an excess of exports over imports implies an excess of items 2 to 66 on the debit side over times 2 to 6 on the credit side. That is to say, it implies an excess of one, any or all of them. Let us consider these in turn in the order given.

In so far as an excess of exports means that Americans are paying interest, dividends, rent, etc., to foreigners who own our resources and equipment, it is certainly unfavorable. This is tribute for which our foreign landlords return absolutely nothing. His draft is a draft upon our exports—economically he is paid with our exports. Many Englishmen own large farming tracts in America and these they divide up and let out to tenant farmers who render a very large part of the crop in rent. The owners for the most part remain in England, and thus there is a large export from America for which there is no return. The tribute exacted by Germany of France in 1871 caused a large excess of French exports over her imports. When Rome was mistress of the world, the wealth of the provinces was drained to her by taxes, tribute and rent for which no return was made. Her trade weighed heavily on the side of imports, yet it was a most "favorable" trade for her. We are cheerfully told that the picturesque Russian provinces in the Caucasus flourish under an export trade five times larger than the import. What does it mean? Probably that the greater part of the district is owned by Russian noblemen living in St. Petersburg, whose rents reach them through this heavy export trade. So in India, the "home charges" of an alien government and the remittances of alien officials cause a permanent excess of exports over imports.

In regard to item 3 let us suppose that Americans were to regularly

invest the same amount in foreign securities each year. At the end of the twentieth year, interest on twenty such annual investments would be due, and if the rate of interest was five per cent. or 1/20, the return to our country in interest would just balance the yearly purchase of securities. That is to say, item 2 on the credit side would just offset item 3 on the debit side. Or if this interest was compounded or more than compounded by an ever increasing annual investment by Americans, the annual purchase of foreign securities might indefinitely exceed the interest returns on them. But it is not only inconceivable that the annual investment should continually increase, it is inconceivable that it should remain constant. It is quite possible that any of these things might occur for one year or for a number of years, to be offset in other years by reverse flows, but that in the long run, or as a continuous process, our investments should regularly exceed the returns from them is impossible. The process of investing is a process of saving or creation of capital goods, and it is well understood that the amount of capital goods the world can use is limited. With the progress of invention this amount would increase and might increase rapidly, but could not increase indefinitely. Static periods and periods of decline must alternate with these rises, in which the capital in existence is sufficient and there is no saving at all. Mankind generally must forever produce and consume as a continuous process, but mankind generally can not save as a continuous process. The moment a certain limited and sufficient capital stock is brought into existence, saving must cease, for there is no gainsaying the principle that men seek to satisfy their wants with a minimum of effort. If mankind does not consume what can not be invested, then his wants can be satisfied with both less labor and less capital.

We conclude then that our annual purchase of foreign securities can not regularly exceed the interest returns from them, for if such were the case it would mean that Americans were gradually and surely acquiring the resources of the rest of the world at the same time they were receiving no net return.

Statistics showing the country's status in regard to items 2 and 3 are difficult to obtain. In *The Review of Reviews* (April, 1915) is a pertinent discussion of the billion-dollar export balance augured for 1915, and its relation to these "invisible factors" of international trade. We will quote from this in part, and in reading it the fact that our export balance has hovered around the half-billion mark for the last four years should be borne in mind. For the four years ending with 1914 the balance was 522, 551, 652 and 470 millions, respectively, so we may fairly say the normal excess is roughly half a billion dollars, and that the billion-dollar excess for 1915 is an abnormal excess induced

by the sudden call of Europe for war material. On page 403 of the review we read:

. . . Sir George Paish has estimated that the item of freight and insurance charges is probably not more than $25,000,000. Competent statisticians have put our annual net return on indebtedness abroad at $300,000,000,—from which a deduction of $50,000,000 should be made for returns on American capital employed in foreign countries. Adding to these offsetting items the remittances to relatives and friends of the laborers, the statisticians figure that from the face figure of our favorable balance there should be deducted perhaps $500,-000,000. On this basis we should for 1915 have a final net balance in our favor of more than half a billion dollars.

How Will Europe Settle With Us?

This does not however allow for the returns from foreigners of our securities which they have held and now sell back to us. The total of our securities held abroad is generally estimated to be about $6,000,000,000. It is certain that during the last few months a considerable fraction of this great total of bonds and stocks has been sold back to Americans, although the situation is too complicated to determine just how much. But at any rate it is difficult to see how Europe will settle her growing balance of indebtedness to America in any other way than by returning yet more of these securities. The summary way of settling the current debt would be by sending gold to New York, but in the first place the countries at war will not give it up, and in the second place it would not be desirable from our own point of view, as we have a plethora of gold at present.

It may fairly be inferred that the figures representing securities and returns therefrom are for normal conditions just before the war. It is most instructive to note that the statisticians show a substantial balance of the international debit and credit account for the normal years. They say about 500 millions should be deducted from the face figure of our favorable balance, and this lacks only one tenth of the average balance of trade for the four normal years. About one half of this they account for through our item 2, and for the rest items 5 and 6 are mentioned, although we suspect that item 4 for normal years was also included.

So much for what the figures show us as to normal or "running" conditions. That half of the billion-dollar balance not accounted for at the end of 1915 is the temporary balance which will be, must be, wiped out when we are able to average up the account with a few of the years yet to come. The transactions of 1915 are especially incomplete. But we can not insist too strongly that this temporary balance is not the so-called "balance of trade." The one is a balance about to be settled, the other is a running balance that will never be settled. Such a temporary balance can be counted as neither favorable nor unfavorable, for if the fact of having something due us is favorable, the payment of the due is a cancellation of the favor. No one will contend that it is favorable to a creditor that the debts he holds should never be

settled, yet only by such a system could his credit balance attain a maximum.

"How will Europe settle with us?" If we examine the debit side of our international account it appears that item 3 furnishes her only means in this time of her stress. Being too busy with war to make commodities for us, she must sell us her securities or sell us back our own securities or negotiate a loan from us. Each of these methods is at base a loan and on each Europe would have to pay interest.

Let us suppose that Europe has settled this half billion temporary balance by the transfer to us of the ownership of securities to that amount. And further let us suppose that after the war we are content to retain those securities and that Europe is unable to rebuy them. What permanent change has the war made in our trade balance and in whose favor is it? Clearly we shall be paying less interest and Europe more, to do which we must send her less goods and she send us more. Our balance of exports will be reduced or turned into an import balance and the movement will be in our favor. The heavy dealings in item 3 having ceased with the settlement of the abnormal temporary balance of trade, the large running balance in item 2 on the credit side will be offset by a large running balance in item 1 on the debit side. Europe can not forever settle this running debt of interest by continually incurring more debt or selling securities. If she is not to totally impoverish herself, she will sooner or later have to settle by swelling our imports with the tangible results of her labor.

An excess of exports may mean that there is much American travel abroad. Some say that it is a drain upon the United States for Americans to take their vacations abroad, because it gives the hotel business to Europeans instead of Americans. If this were true it would of course be an argument against the "favorable balance of trade" idea. As a matter of fact the travel abroad is neither a drain nor a benefit. If it gives hotel business to Europeans, it also gives an equal business to manufacturers of exports in the United States. What the travelers get in Europe is paid for with exports from the United States. Or we may look upon it in this way. In serving travelers, Europeans are taken out of other fields of production in which they would otherwise have produced for their own consumption. Their own consumption is now satisfied by producers in America, who export to the European market more than they otherwise would export, to just the extent of the drafts on America presented by our travelers at the European exchanges. Or, prospective American travelers produce wealth in America which they save, and consume later in Europe. What they nominally take with them is a letter of credit, but what they take economically is a certain quantity of exports which the letter of credit or other instrument releases from the American shores.

An excess of exports may mean that most of the ocean carriage is done in foreign bottoms, the excess being freight for carriage. Here again we see that if the business of carrying is taken away from us, an equal business of manufacturing the exports with which to pay the carriage is given to us. Any argument favoring the building up of our merchant marine is against the "favorable balance of trade" idea.

Items 4 and 5, then, do not seriously enter into the argument of the balance of trade, because it is easy to see that value is given for value received. They are the only cases of an export balance that is not unfavorable. But, be it observed, neither is their balance favorable.

Unlike the last two items we have discussed, remittances to friends are gifts for which there is no return. In so far as an excess of exports means that people in America are sending gratuities to Europeans, it is an economic drain upon America.

Our answer, then, to the question which has been the subject of this discussion—is a balance of trade in favor of exports favorable?—is an unqualified negative. We have seen that the export balance induced by travel abroad and the use of foreign bottoms is neither favorable nor unfavorable, and that the balance induced by the joint action of all other causes is unfavorable. Foremost among these other causes is the joint action of items 2 and 3 in which we have seen that item 2 must predominate. We have seen that the "gold question" might be used to support our negative did it have existence in fact, but we have also seen that in modern times its existence in fact is negligible. The parts of the problem which outweigh all others in considering the economies of a modern nation like the United States are to be seen in a survey of items 1 and 2. If we include the terms interest, dividends, rent, profits, under the single term interest, then we may say that an excess of exports means that a country pays more interest than it receives, that it is giving without receiving, that its resources are owned abroad when they might be owned at home.

Our conclusion is directly contrary to the current notion. So widespread and ingrained is the idea that an export balance constitutes a gaining trade, it is not sufficient for us to disprove it—we must account for it.

Our ideas regarding the actions of states and nations usually find their counterpart in our ideas regarding individuals. Probably the idea that it is more profitable to export than to import receives currency through the idea that it is profitable for a man's sales to exceed his purchases. This idea is a true one only when we have in mind a part of his life, his business life—only when we exclude from the term purchases, his purchases for consumption. We usually reckon profit or income upon money or credit outstanding, but this is a potential profit

which does not materialize until converted into goods or services for consumption. Now money or credit is merely a sign of uncompleted exchange, and a man's exchanges are not complete save to the extent that he has spent outstanding money or credit for goods or services for consumption. What we really have in mind when we say selling is better than buying is that a large excess of a man's sales over his purchases of capital goods is profitable *because* it is followed by a large purchase of consumable goods. Dealings in capital goods are profitable only *because* of this. The fallacy in transferring the idea to international trade lies in slurring over just this usually unexpressed qualification. With the man we are thinking of his uncompleted exchanges, while with the nation the "balance of trade" is an item in a balanced account of completed exchanges, and to that extent it is not a balance at all. With the man, his excess of sales is a credit, a lien upon the market, while with the nation her excess of exports is not a credit. That the trade balance is not a credit appears in startling form when we begin to look about for tangible evidence of credit. No one is puerile enough to believe that the nine-billion-dollar export balance of the United States, accrued during twenty-five years, is a lien to that extent upon the wealth of other nations and that either American citizens or the American government hold mysterious papers that have the power to recall nine billions of foreign wealth to our shores when we shall choose to have it. And if any doubts remain as to a certain store of gold, it is only necessary to remember that that nine billions is over and above all exports paid for with gold.

The current idea in regard to the balance of trade is closely associated with the doctrine of protection and the popularity of that doctrine is doubtless another source of the support the trade-balance idea receives. Those who believe in the protective tariff will believe in the "favorable balance of exports." In this connection its fallacies are obscured by the ease with which people are impressed with the concrete good or evil of an individual or small group of individuals, and the difficulty with which people are impressed with the general good or evil diffused over the whole community. It is doubtless true that protection and restricted imports are favorable to *some* Americans, but it can only be so at the expense of all other Americans, for we have seen that it is not favorable to the community as a whole.

But the question of the balance of trade here stands clear cut and apart from the tariff controversy, of which it forms an independent part. In the light of our demonstration it may fairly be said that of all popular fallacies it would be difficult to find another so groundless, so contrary to our simplest intuitions, and so readily capable of disproof, as the notion that it is more profitable to send things away than to take them in.

FIRE INSURANCE AND PROTECTION FROM FIRE

By MAYNARD M. METCALF, Ph.D., Sc.D.

The Orchard Laboratory, Oberlin, Ohio.

THE average annual loss by fire in America is over half as much as the cost of building the Panama Canal. This is an actual loss. Insurance, of course, restores nothing destroyed, but merely passes the hat for the benefit of the individual losers. The loss to the community is total. There are great benefits to the community from the payment of insured losses. It provides for the continuance of business with the least interruption and removes from individual losers much of the feeling of disaster and panic. This is of great moment to the community, but it does not repay to the community any of the loss actually incurred through the fire. It merely prevents still further loss from delayed recuperation.

But little thought has been given to the communal aspects of the economic system of fire insurance. It has been viewed chiefly from the standpoint of the individual. Insurance companies repay to individuals their actual losses and it is simpler for the individual to gain security against loss by fire by hiring an insurance company to carry his risks than it is for him to prevent loss from fire by building fireproof buildings. Indeed, experience has shown that "fireproof buildings" of the highest grade are not safe against great fires which have gained full headway and sweep in full force upon them from the outside. Fireproof construction of single buildings does not make them safe, if they are surrounded by burnable buildings. In the great Baltimore fire a heat of over 3,000 degrees Fahrenheit was generated, as was shown in three different regions when, after the fire, dentist's porcelains, fusible at that temperature, were found melted by the heat. The best fireproof construction does not protect a building from such temperatures. Marble crumbles; granite, especially if touched by water or its vapor, disintegrates; structural steel warps and twists.

After the Baltimore fire, there was in Baltimore much discussion of fire insurance and a little discussion of fire-fighting, but the author heard only one man mention the matter of fire prevention. Of course, from the standpoint of the prosperity of the country this matter of fire prevention was the one which should have received chief attention.

Two effective methods of protection against fires have been devised —first, fireproof construction and, second, automatic water sprinklers.

Fireproof construction is a safe protection against fires starting within the building, but not against major fires advancing upon the building from the outside. This device is the most expensive yet suggested, and to be effective it must apply to all buildings in a city. Berlin and Paris are pretty well protected in this way, but Tokyo, with its frail house construction and paper partitions, all of highly combustible material, would find this method of protection from fire of prohibitive expense.

Automatic water sprinklers have proved effective, reducing insurance costs by all the way from one third to nine tenths under different conditions. In the Baltimore fire, O'Neil's four-story department store stood in the direct path of the fire, but the curtains of water automatically thrown over its windows prevented the fire entering these and though the fire entered in three places beneath the roof the automatic sprinklers within extinguished it in each place. Indeed it was O'Neil's store, thus protected, which helped turn the fire eastward toward the little stream on whose banks it was finally checked. Water sprinklers are effective and are usually able to confine any internal fire to the room in which it arises, and similarly water curtains, outside windows and doors have proved efficient against fires approaching from without, in the few instances in which they have been tried. But the damage from water is a serious consideration and therefore automatic water sprinklers have by no means solved the problem of fire prevention.

There is need of experimental study of the whole problem of fire prevention—including fireproof construction and immediate extinction of fires at their inception. This subject has never had any real study worthy of the name, in this country or in any other. Roughly speaking, America's annual fire loss is a quarter of a billion dollars,[1] yet the total expenditure in the study of problems of fire prevention has been far less than this sum.

Why is this? Why has this subject been so neglected? The answer is very evident. The economic system of fire insurance, so greatly developed, has removed the individual motive for fire prevention, leaving only the communal motive to urge such protection. Individual security, reached through fire insurance, has made men thoughtless and careless about the loss to the community. It is even true that the collection of insurance serves as a motive for incendiary fires and this to an extent that is an important increment in each year's loss by fire.

The chief need is a government bureau to study experimentally problems of fire prevention in all its aspects. Prevention of forest fires

[1] Including Canada. This figure, of course, varies widely from year to year and considerably from decade to decade. If one of the main theses of this paper is correct and all fires in buildings could readily and inexpensively be suppressed before damage occurs, then a large portion of the cost of maintaining our enormous fire insurance system should be included as part of the "fire waste."

is a very different problem from that of prevention of fires in cities, and this again differs from the problem presented by scattered buildings. We have done something toward the prevention of forest fires, and the Forestry Bureau is giving this problem some good thought. We are doing practically nothing in the study of the problem of prevention of fires among buildings.

The problem is apparently not one of extreme difficulty. There is every reason to anticipate its satisfactory solution after adequate study. In the study of fireproof construction suitable for large public and commercial buildings, structures of many types should be built and burned and scientifically accurate knowledge obtained as to their behavior under conditions paralleling the real conditions of actual fires. Still more important is study of prevention of fires among inflammable buildings. The problem will not be solved until inexpensive methods are devised which will prevent any fire getting beyond the room in which it originates, however inflammable be the material of the building itself or of its furnishings, and the substance used in thus putting out the fire at its start must not be water but must be something that will not itself do damage to the most delicate fabrics. It is quite likely that automatic sprinklers throwing chemical fire-extinguishing substances may be found to meet the need. If it proved best to use substances injurious to human beings, automatic alarms could be used in all chambers or other inhabited rooms to rouse the occupants before the discharge of the deleterious chemicals. But discussion of such details is not appropriate here.

Suppose we should appropriate a quarter of a billion dollars, the amount of a single year's fire loss, to the organization and support of a Bureau of Fire Prevention, calling to the work of this bureau the three best chemists, the three strongest physicists, and the three keenest engineers in the world. How long would it be before they had found very inexpensive methods of protecting all buildings against fire, however inflammable their construction? The problem is childishly simple beside those which men of science are attacking daily and with success.

How absurd it is that we have fires to-day! They should long ago have become a thing of the past. On the Sunday when the great Baltimore fire broke out, the author was standing in the door of one of the churches after service, talking to the Reverend Dr. D'Aubigny, of Paris. When a hook-and-ladder wagon galloped past Dr. D'Aubigny asked, "What is that?" On being told it was fire-fighting apparatus on the way to a fire he said, "Oh! That is something I must see, an American fire. We do not have them in Paris." Paris, without serious study of fire prevention, has taken the expensive method of fireproof construction. We can well afford to use this same method for large public and commercial buildings, but we need also to install in all buildings, as

they now are, inexpensive devices that will at once extinguish any fire in the room in which it originates.

The economic system of fire insurance under private management, as it has developed, has suppressed individual initiative in fire prevention, has distracted attention from the real problem and has been the actual cause of postponing its solution for these many years. As developed, the system has proved one of the most colossal economic blunders, as it is one of the most absurd and childish. For thirty years the author has been interested in this subject, but only during the last five years has he seen any discussion of it, either scientific or popular, and never has he found any recognition of the utter economic absurdity of the present system of dealing with fire. There are a few glimmerings of awakening interest. Let us hope they prove an earnest of a genuine and adequate attack upon the problem.

THE BLACK DEATH, AND ITS LESSONS FOR TO-DAY

By Professor T. D. A. Cockerell
UNIVERSITY OF COLORADO

WE are often told that the present European war is the greatest calamity the world has ever known, and as such, it paralyzes the minds of men, whose normal reactions are totally inadequate in the presence of such extraordinary conditions. Future students of the history of the twentieth century will read the chronicle with despair or boiling indignation, according to their temperaments, asking why, in heaven's name why, were those people so utterly incompetent to do the simple things which might have prevented the catastrophe? In many respects, there is little resemblance between the fourteenth century and the twentieth, and less between the bubonic plague and war; yet it may not be unprofitable to consider that other enormous European calamity, of the years 1348–9, and its effects upon the stricken populations.[1] Although the cause of death and loss was different, the results were in many respects similar, and if the attempts of our ancestors to deal successfully with the situation now seem to us amazingly futile, we may at least ask ourselves whether we are exhibiting any better judgment to-day. In the fourteenth century the microscope was of course unknown, and it was beyond the powers of the wisest man to learn anything about the *Bacillus pestis* or its communication to man by the rat flea. At the same time, the uncultured people of many times and countries had reached sound empirical judgments; and the beginnings of science in remote antiquity had promised something better than the dominance of unreasoning superstition posing as religion. Was it not a fact that the cult of the ruling classes had so imposed itself on the masses that for centuries the free action of the mind, in observing relations between cause and effect, had been inhibited? Is it not a fact to-day that a similar cult, that of the necessity and propriety of war, acts as a like inhibitor to those mental reactions which might otherwise clarify the atmosphere and make easy the way to peace? The problem of the fourteenth century was a terrific one, as is our problem to-day. Even a partial solution would have required the utmost exercise of all the wisdom available; but the point is, that then as to-day, men cravenly ac-

[1] My principal sources of information have been Dr. F. A. Gasquet's "The Great Pestilence" (London, 1893), and Mr. Edgar Powell's "The Rising in East Anglia in 1381" (Cambridge, 1896).

cepted as inevitable what might conceivably have been prevented. Petrarch in Italy thus wrote to his brother in June, 1348:

Alas! my beloved brother, what shall I say? How shall I begin? Whither shall I turn? On all sides is sorrow; everywhere is fear. I would, my brother, that I had never been born, or, at least, had died before these times. . . . When has any such thing been ever heard or seen; in what annals has it ever been read that houses were left vacant, cities deserted, the country neglected, the fields too small for the dead, and a fearful and universal solitude over the whole earth? Consult your historians, they are silent; question your doctors, they are dumb; seek an answer from your philosophers, they shrug their shoulders and frown, and with their fingers to their lips bid you be silent. Will posterity ever believe these things when we, who see, can scarcely credit them? We should think we were dreaming if we did not with our eyes, when we walk abroad, see the city in mourning with funerals, and returning to our home, find it empty, and thus know that what we lament is real. Oh, happy people of the future, who have not known these miseries and perchance will class our testimony with the fables. We have, indeed, deserved these (punishments) and even greater; but our forefathers also have deserved them, and may our posterity not also merit the same.

In France, in many places, two thirds or more of the population died.

In many towns, small and great, priests retired through fear, leaving the administration of the sacraments to religious, who were more bold.

At the hospital in Paris, for a long time more than fifty corpses were carried in carts to burial daily. The devout sisters of the hospital, like those of to-day,

worked piously and humbly, not out of regard for any worldly honor. A great number of these said sisters were very frequently summoned to their reward by death, and rest in peace with Christ, as is piously believed.

The chronicler (William of Nangis) notes disastrous after effects:

Alas! the world by this renovation [after the plague] is not changed for the better. For people were afterwards more avaricious and grasping, even when they possessed more of the goods of this world, than before.

Moreover, all things were much dearer; furniture, food, merchandise of all sorts doubled in price, and servants would work only for higher wages.

Philip VI. of France did indeed at the eleventh hour take a wise step. He called the medical faculty of Paris together to consult as to methods for combating the disease. Apparently the only advice the doctors could give was to avoid the sick. The king of Sweden, Magnus II., was more in accord with the spirit of the times. He issued a preparedness proclamation, advising every one to abstain on Friday from all food but bread and water, "or at most to take only bread and ale," to walk with bare feet to church, and to go in procession around the cemeteries carrying the holy relics.

The approach of the plague to the shores of England soon caused

apprehension. The Bishop of Bath and Wells sent letters through his diocese ordering processions every Friday in each collegiate, regular and parish church, and granting an indulgence of forty days to all who, "being in a state of grace, should give alms, fast or pray, in order, if possible, to avert God's anger." The coast of Dorsetshire seems to have been the first part infected, but the disease spread rapidly through the country. Gasquet remarks: "it is curious to observe how closely the epidemic in this country clung to the rivers and water-courses," a suggestive observation now that we know the connection of the disease with rats. "The mortality," says the same writer, "attacked the young and strong especially, and commonly spared the old and the weak"—its effects here being comparable to those of war. Just as to-day, Oxford and Cambridge were depleted of their students; and although to-day we honor and admire the many hundreds of young men who have left their colleges to fight for their country, we may no less than the men of the fourteenth century deplore the deaths of so many of those who were expected to lead the intellectual forces of the nation. In the earlier period, when the universities existed primarily for the education of the clergy, the loss fell upon the church, which suffered in many ways; to-day the injury will necessarily be more general, and if less conspicuous, no less serious. Dr. Gasquet, in a most interesting and instructive final chapter, sums up "some consequences of the great mortality." These consequences were good and bad, but of tremendous importance in either case. From the Norman conquest up to the middle of the fourteenth century, the nobility and gentry conversed in French, and their children were taught in that language. A schoolmaster named Cornwall introduced English into the instruction of his pupils, "and this example was so eagerly followed that by the year 1385, when Trevisa wrote, it had become nearly general." This change, the author suggests, could never have been effected had not the plague carried off so "many of those ancient instructors," that the opposition to it could be overcome. Thus was the English of Shakespeare made possible.

In architecture, the effects of the epidemic are still visible to-day. In many cases buildings which had been begun were never finished; or if finally completed, it was in another style which had since come into vogue. There is similarly a break in the development of stained-glass manufacture; first an interval, and then the resumption of work showing a change of style.

The tremendous shock to people's minds and habits produced a reaction which, in the long run, led to good results. But the disorganization let loose much evil, and Gasquet is obliged to state:

> It is a well-ascertained fact, strange as it may seem, that men are not as a rule made better by great and universal visitations of Divine Providence.

It was noted of the great plague in the reign of the Emperor Jus-

tinian, that "whether by chance or Providential design it strictly spared the most wicked," and it was "the universal testimony of those who lived through" the period of the Black Death, "that it seemed to rouse up the worst passions of the human heart, and to dull the spiritual senses of the soul." Nevertheless the author is able to present a better side, and his words are so eloquent and so significant for modern times that I quote at length:

> In dealing with this subject it is difficult to bring home to the mind the vast range of the great calamity, and to duly appreciate how deep was the break with then existing institutions. The plague of 1349 simply shattered them; and it is, as already pointed out, only by perpetual reiteration and reconsideration of the same phenomena that we can bring ourselves to understand the character of such a social and religious catastrophe. But it is at the same time of the first importance thoroughly to realize the case if we are to enter into and to understand the great process of social and religious reedification, to which the immediately succeeding generations had to address themselves. The tragedy was too grave to allow of people being carried over it by mere enthusiasm. . . . It was essentially a crisis that had to be met by strenuous effort and unflagging work in every department of human activity. And here is manifested a characteristic of the middle ages which constitutes, as the late Professor Freeman has pointed out, their real greatness. In contradistinction to a day like our own, which abounds in every facility for achievement, they had to contend with every material difficulty; but in contradistinction, too, to that practical pessimism which has to-day gained only too great a hold upon intelligences otherwise vivacious and open, difficulties, in the middle ages, called into existence only a more strenuous and more determined resolve to meet and surmount them. . . . Many a noble aspiration which, could it have been realized, and many a wise conception which, could it have attained its true development, would have been most fruitful of good to humanity, was stricken beyond recovery. Still no time was wasted in vain laments. What had perished was perished. Time, however, and the power of effort and work belonged to those that survived.

Subsequent to the plague of 1348–9, and its recurrence in 1361, the conditions of labor were greatly altered, in ways presenting an interesting parallel to what we see going on to-day. Mr. Edgar Powell, in his account of "The Rising in East Anglia in 1381," takes up this phase of the subject, giving many details. In the rural districts great numbers, in some places nearly one half, of the population had been swept away, and naturally the supply of labor was extremely scarce. This led to a demand for higher wages, but the landowners, quite unable to adjust themselves to the new conditions, resisted by every means in their power. They even secured legislation establishing—not the minimum wage we hear so much of to-day—but a *maximum* wage, with punishments for all those who gave or received more. The principal result of this was to exasperate the working classes, who were further infuriated by the severe penalties which the law permitted; even, if the prosecuting individuals desired, extending to branding the foreheads of those convicted. Added to all this, came the heavy burden of the poll-tax, which was the final

and immediate cause of revolt. New ideas of liberty, fraternity and equality, the germs of our latter-day socialism, filled the air; and those who began by rebelling against an excess of injustice, now looked forward to a veritable heaven upon earth. William Morris, in his "A Dream of John Ball" (1890), has given us an idealized version of the rebellion, centering about the personality of that "rascal hedge-priest" John Ball, who seems to have chiefly represented the idealism and intellect of the movement. "Yea, forsooth," Morris supposes Ball to say, "once again I saw as of old, the great treading down the little, and the strong beating down the weak, and cruel men fearing not, and kind men daring not, and wise men caring not; and the saints in heaven forbearing and yet bidding me not to forbear; forsooth, I knew once more that he who doeth well in fellowship, and because of fellowship, shall not fail though he seem to fail to-day, but in days hereafter shall he and his work yet be alive, and men be holpen by them to strive again and yet again; and yet indeed even that was little, since, forsooth, to strive was my pleasure and my life."

The revolt was crushed, and had it not been, it could not have accomplished its proper purpose. Time was needed for that, but the old condition of affairs never quite returned, and much of what we cherish most to-day had its remote beginnings in that apparently fruitless struggle. After the present war, in the readjustment which must necessarily take place there will be opportunity and necessity for reform Will it be possible to approach the problem with an eager desire to make the best of the situation, or will those in power stubbornly resist every fundamental change? In particular, can we throw off the burden of militarism by appealing to the intelligence and good-will of mankind; or will the populace, finally goaded to desperation, be driven to revolution? As in the fourteenth century, we are borne on the crest of a wave which we can not stem; up to a certain point, we are compelled by the course of events,—but it will make all the difference in the future whether we now approach our problems intelligently or with ignorance and prejudice. A great catastrophe, whether plague or war, breaks many links with the past, and gives the surviving generation new power and new opportunity. Thus, to an unusual extent the deeds of that generation affect those to come, and heavy is the responsibility if a false start is made.

An apparently good authority (Hecker) estimated that in the fourteenth century the bubonic plague destroyed about twenty-five millions of persons, with the various results briefly indicated above. Yet historians have been so blinded by the political and military aspects of history that they have been unable to sense the significance of these tremendous events. As Gasquet remarks,

Judged by the ordinary manuals, the middle of the fourteenth century ap-

pears as the time of England's greatest glory. Edward III. was at the very height of his renown. The crushing defeat of France at Crecy, in 1346, followed the next year by the taking of Calais, had raised him to the height of his fame. . . . It is little wonder, then, that the Great Pestilence, . . . coming as it does between Crecy and Poitiers, and at the very time of the creation of the first Knights of the Garter, should seem to fall aside from the general narrative as though something apart from, and not consonant with, the natural course of events.

Consequently Hume and others "dismissed the calamity in a few lines," and even J. R. Green, who had a more intelligent grasp of historical sequences, "deals with the great epidemic in a scanty notice only as a mere episode in his account of the agricultural changes in the fourteenth century." Will the historians of the days to come record the present era as one of glorious victories and splendidly dominant monarchs; or will they know what those now engaged in battle can not fully know, that the masses on both sides had a common cause and a common enemy?

RESOURCES IN MEN

By Brigadier-General H. M. CHITTENDEN, U.S.A. (ret.)

Seattle, Wash.

THE war has progressed far enough to convince most people that its outcome is no longer dependent upon the state of preparation before it began, but rather upon the future endurance of the belligerents. This endurance relates, first, to resources in men, and, second, to resources in wealth. It is proposed in this article to analyze with some care the question of resources in men, for there can be no doubt that the struggle has reached a stage with some of the belligerents where this question is causing anxiety.

To begin with, what proportion of the total population is available for military service? That depends both upon the age limits and the physical standard in force in the country considered. When there is a superabundance of material, very rigid qualifications are likely to be insisted upon. Thus in our country in time of peace the age limits are 21–35, extending to 18 with the consent of the parent or guardian; but the requirements are so strict that, even within these limits, which cover only the most robust period of life, three out of four applicants on the average are rejected.[1]

The standard military age the world over has long been 18–45, the upper limit being at the forty-fifth birthday. It is universally recognized that approximately two fifths of the total population fall within these limits. The exact figures for certain countries and censuses are exhibited in the following table and shown graphically on the accom-

Proportion of Population between Specified Age Limits

Specified Age Limits	England and Wales, Census 1911	Germany, Census 1910	France, Census 1906	United States, Census 1910
0 to 14 inclusive	30,637	34,051	26,021	32,098
15 to 59 inclusive	61,327	58,073	61,398	61,141
60 and upward	8,036	7,876	12,581	6,761
For all ages	100,000	100,000	100,000	100,000
18 to 44 inclusive	42,406	39,727	40,190	43,100
17 to 49 inclusive	47,756	46,700	47,901	49,900

[1] Probably this is not a true criterion of the military availability of the population, for the reason that in this country, where such high wages prevail, it is generally men of defective working ability that seek enlistment.

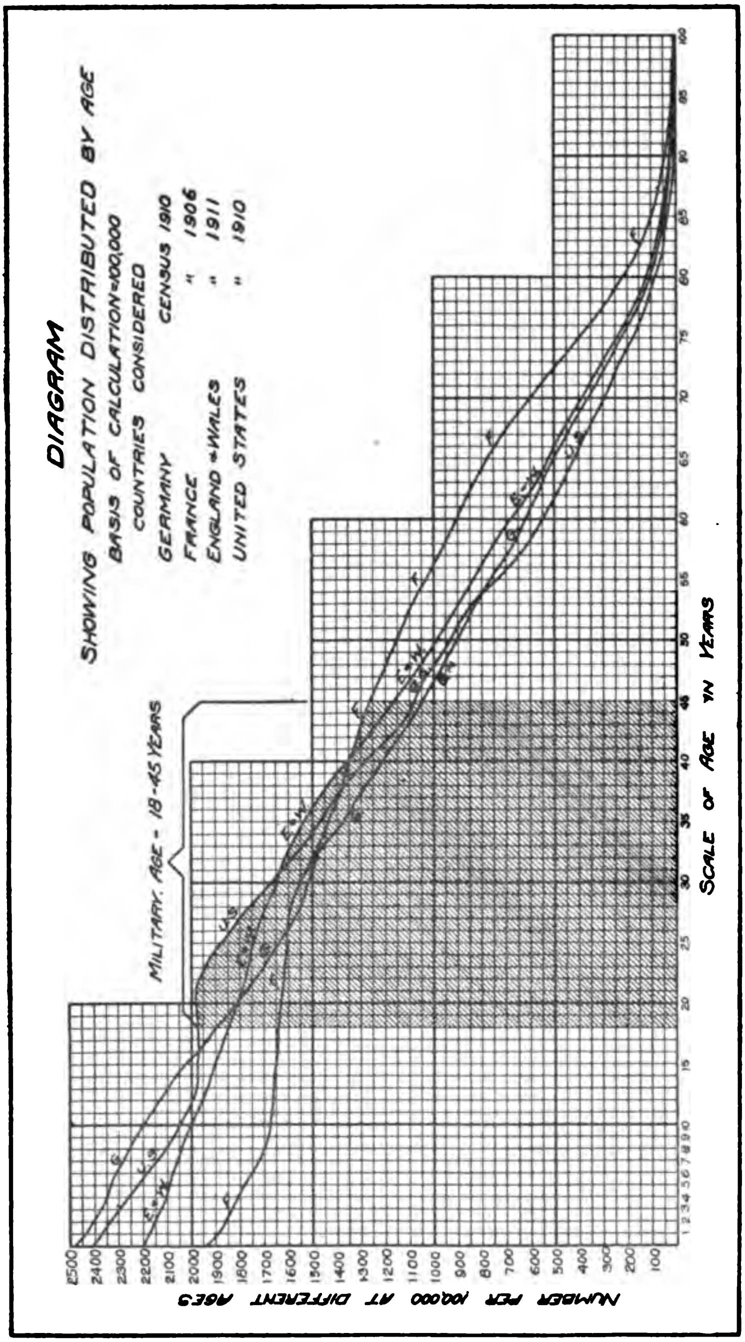
DIAGRAM
SHOWING POPULATION DISTRIBUTED BY AGE
BASIS OF CALCULATION=100,000
COUNTRIES CONSIDERED
GERMANY CENSUS 1910
FRANCE " 1906
ENGLAND + WALES " 1911
UNITED STATES " 1910
MILITARY AGE - 18-45 YEARS
SCALE OF AGE IN YEARS
NUMBER PER 100,000 AT DIFFERENT AGES

panying diagram. For purposes of comparison of different countries, both the table and diagram are based upon a population of 100,000. To pass from these to the actual figures for any country, multiply the quantities taken from the table or diagram by the total population divided by 100,000. The age limits, 17–50, are separately given in the table because of their actual adoption by the Confederate States in the American Civil War.

The graphic presentation of these results is instructive and easily understood even by the uninitiated in that method of illustration. To find the proportion of 100,000 at a particular age for any of the four countries, look for the age in the scale at the bottom of the diagram. Then follow the corresponding vertical line until it intersects the irregular line, or curve, for the country considered. Next follow the horizontal line through this point of interesection to the vertical scale on the left and read off the corresponding number. The area of the diagram bounded by the vertical and horizontal scales and by any one of the curves represents 100,000 population; and the shaded area the proportion within the age limits, 18–45.

We may now make clear what puzzles a great many. We think of the immense numbers born each year, or arriving at military age, and it seems as if the supply must be rapidly increasing. We do not so readily see the annual decrease which offsets it. Look on the diagram at the vertical line representing age 17. Next year that will pass over into 18, the military age. But at the same time the line 18 has passed into 19, slightly shortened, however, through the deaths that have occurred during the year. In like manner 19, similarly shortened, has passed into 20. So on through the whole series until finally 44 passes into 45 and out of the military age altogether. With constant conditions as to the birth and death rates, the sum of the numbers by which the several years are shortened by death and of the numbers passing over into 45, or out of the military age, exactly equals the numbers passing in from 17 to eighteen. Thus it is a continuous process of gain and loss, the balance remaining constant for a fixed condition of the population.

Particularly interesting are the characteristic features of the population movement in different states, as disclosed by the diagram. The high birth rate of Germany and the low birth rate of France are clearly indicated. Germany is a nation high in its percentage of youth; while France is high in the middle and old age periods. England falls between. The United States begins with a curve similar to that of Germany; but from about the age of 13 it ceases to decline and continues practically horizontal for the next ten years, which places it, at 23, far above any other country. This is entirely due to the influx of immigrants, which is strongest in the ages 15–30, with a maximum at 21–25. The reverse effect would undoubtedly be apparent in countries from which there is a proportionately heavy emigration.

The proportion of population within the age limits 18–45 being about 40 per cent. of the total, and about half (in Europe a little more than half) being women, there remain one fifth men, as already pointed out. But not all of these are available for military service. Some are physically unfit and some have to be retained at home to do the necessary work. What these exemptions amount to depends upon the physical standard adopted, and upon the requirements of home service and the ability of the non-military population to perform it. In the Confederate service at the close of the Civil War a most rigid draft was enforced. In a white population east of the Mississippi, of about 3,600,000 (Negroes were not taken into the service to any appreciable extent) the number of exempts which had to be allowed between the ages 17 and 50 was 87,863, or about 10.3 per cent. of the male population within these limits.

RESOURCES IN MEN

Name of Country	Latest Estimates of Population	18 to 45 Years, 16 %	17 to 50 Years, 18.8 %	Arbitrary, 10 %
Germany	(1916) 67,812,000	10,850,000	12,740,000	6,718,000
Austria-Hungary	(1910) 51,814,000	8,290,000	9,741,000	5,181,000
Turkey	(1910) 20,000,000	3,200,000	3,760,000	2,000,000
Bulgaria	(1914) 4,750,000	760,000	873,000	475,000
Total	144,409,000	23,1000,000	27,123,000	14,374,000
Russia	(1912) 173,356,000	27,737,000	32,591,000	17,336,000
United Kingdom	(1913) 46,185,000	7,390,000	8,683,000	4,619,000
France	(1911) 39,602,000	6,336,000	7,445,000	3,960,000
Italy	(1911) 35,239,000	5,638,000	6,625,000	3,524,000
Belgium	(1912) 7,571,000	1,211,000	1,423,000	757,000
Servia	(1914) 4,547,000	732,000	855,000	455,000
Montenegro	(1914) 516,000	83,000	97,000	52,000
Colonies	25,000,000	4,000,000	4,700,000	2,500,000
Total	322,016,000	52,127,000	62,419,000	33,203,000
Roumania	(1914) 7,508,000	1,201,000	1,412,000	751,000
Greece	(1914) 4,821,000	771,000	926,000	482,000
Total	12,333,000	19,720,000	2,338,000	1,233,000

The figures in column 2 are from the Almanach de Gotha, except those for the Balkan States, which are from the Statesman's Yearbook. They are given to the nearest thousand only. The Belgian, Serbian and Montenegrin population is nearly all not available. The estimate for "Colonies" is purely arbitrary, but it would be manifestly wrong to make the basis that of actual population.

For the age limits 18–45 the percentage may have been as low as ten, but this must be considered as a minimum under any circumstances. It would ordinarily be considerably higher. Most of the exempts in the Confederate service were such as were physically or mentally unfit, as negro slave labor made it unnecessary to retain many white men for work

at home. But this exceptional resource is now nowhere available, and an additional percentage must therefore be deducted. What this should be it is difficult to say, but it is certainly not less than ten per cent.

It thus results that the male population of military age (20 per cent. of the whole) must itself be reduced by at least 20 per cent. This leaves 16 per cent. of the total population between the ages 18 to 45. A similar deduction gives 18.8 per cent. for the age limit 17 to 50. These figures must be considered maxima which could be realized only under the stress of an emergency so great as to sweep into the ranks practically every available man. In the Confederate service the age limit 17–50 was undoubtedly exceeded, and it was a common saying in those days that the South was robbing both the cradle and the grave to replenish her vanishing armies. Even in the northern army there were enrolled over 100,000 boys of fifteen years or under. Many authorities consider that 10 per cent. of the total population is the practical limit available for the recruitment of armies. The application of these percentages to the several belligerent states is shown in the table on p. 90.

Right here it is important to repeat the caution given in a preceding paragraph that the annual increments to the military age do not mean corresponding increase in the number of men available. How easy it is to make a mistake here is shown by the following recent utterance in one of our most widely read and authoritative periodicals:

> **Germany is growing at the rate of a million a year. That means at least 500,000 fresh soldiers coming into manhood annually.**

Quite evidently, from what we have shown, it means nothing of the sort. The population curves (see diagram) are practically the same for any two consecutive years. Applying these to the actual population of any country in which the population is increasing (of course there is no increment in a stationary population like that of France) it will be found that the annual increment is distributed throughout the whole period of life in practically the same proportion as shown in the diagram. This gives a maximum of 16 per cent. available for duty between the limits 18 to 45. Applied to the assumed annual increase in German population of one million (it is actually a little less than that) we have 160,000 instead of the 500,000 assumed by the author quoted, and even this is probably too great.

Thus far we stand on comparatively sure ground. But we find ourselves on very slippery ground the moment we attempt to determine the extent to which the present war is drawing upon these resources. The best estimates that can be made are largely guesses. We shall here make two arbitrary assumptions which we consider maxima and minima and somewhere between which the actual facts probably lie. Assume

first that the maximum number of men under arms and available for duty when the war is at its height is, for the Allies, 8,000,000 men, and for the Central Powers, 6,000,000. Assume also that the annual losses from all causes (killed, wounded, missing, etc.) will average for the Allies 3,000,000, and for the Central Powers, 2,500,000. Under these assumptions the draft on available resources, in order to maintain maximum strength and make up for losses, will be at the end of the second and third years of the war:

For the Allies, 14,000,000 and 17,000,000.

For the Central Powers, 11,000,000 and 13,500,000.

Now let us assume that the maximum strengths will be, for the Allies 10,000,000, and for the Central Powers 8,000,000; and the average annual losses, for the Allies 4,000,000 and for the Central Powers 3,000,000. The figures at the end of the second and third years will then stand:

For the Allies, 18,000,000 and 22,000,000.

For the Central Powers, 14,000,000 and 17,000,000.

Comparing these figures with the footings in the table of "Resources in Men," the drain upon these resources, even under our maximum assumptions, is seen not to be excessive. But this way of putting it is possibly too favorable to the Allies. If their resources could be pooled so as to be available in as complete a sense as are those of the Central Powers, the showing would be more accurate. But this is not the case. The resources of France, for example, will begin to give out while those of Russia are still not taxed to a third of their capacity. Yet the great Slavic reservoir of men is not available for the battlefields of France. Whether it can accomplish its full purpose by bringing pressure to bear upon the eastern front may be open to doubt; but that nevertheless is the rôle which it must play and it must evidently continue to be a part of the burden upon Great Britain and France to help furnish the funds for equipping the hosts of their great eastern ally.

It will be observed that in our estimates we have made no allowance for a possible "robbing of the cradle and the grave," as in the case of the Confederacy during the American Civil War. The additional resources which might thus be made available are quite beyond our powers of estimate. But our study does clearly indicate that the one danger which either side has least to fear, if the present line-up continues, and if measures are made effective for getting men into the ranks, is a deficiency of fighting men. If the crushing weight of either side could be brought to bear against any one unit of the other, as actually happened in the case of the Central Powers against Belgium, Serbia and Montenegro, the situation, so far as such units are concerned, would be very different. But at present that seems not very likely on any large scale. The whole resources are being brought into play over a wide front and the likeli-

hood of separate exhaustion of any portion is rather remote. Nevertheless prophecy is too hazardous to indulge in. It is safe to say this, however, that the strength of either side—or its weakness—is to be measured more directly by its ability in organization, in the production of munitions, and in the efficient marshalling of resources than in the number of men available. This matter of organization goes altogether beyond the mere creation and handling of armies; it is coming to embrace the whole industrial life of the state itself. It has enabled the Teutonic Alliance, with less than half the resources in men of their opponents, to make decidedly the better showing thus far.

WHO PAYS FOR THE PANAMA CANAL

By C. E. Grunsky, Eng.D.

ONE TIME MEMBER ISTHMIAN CANAL COMMISSION

HAD the Panama Canal been constructed by private enterprise subject to rate regulation by the United States, it is safe to say that the owner would have been allowed earnings that would cover operating expenses, including the requirement of replacing all parts thereof as they go out of use, and also a reasonable return on the capital invested in the enterprise. There would have been no allowance for amortization of the capital unless in the special case of a term franchise and a purpose on the part of the United States to acquire the canal during the life of the franchise. On the assumption of perpetual ownership by private parties there would be no sense in allowing the investment to be reduced unless the United States should desire to become a partner in the enterprise to the extent of such reduction.

The American people, as owners, are accountable to the whole world for the management of this enterprise and should make themselves familiar with the fundamental principles which should control the establishment of the canal tolls.

Has the United States constructed the canal for profit?

Has the United States constructed the canal as an investment which is to yield a reasonable return on its cost?

Has the United States made the investment in the canal as a temporary investment which it will endeavor to recover from those who use the canal?

Can the United States afford to make such investments for the benefit of commerce without recovering interest on the investment?

The answers to these questions will guide the economist who fixes the tolls, and will give him his starting point.

If the net earnings of the canal, that is, earnings in excess of operating expenses, are sufficient to meet interest on a bonded debt equivalent to the cost of the canal and enough surplus to return to the United States in a fixed time, as, for example, 100 years, the cost of the canal, then, at the end of this time the United States will no longer be out of pocket anything for canal construction. The nation will be in the same position as though some one had made it a present of the canal. During this time at some regular or irregular rate those who have travelled through the canal, and those who have purchased the goods transported through it, will have returned to the treasury of the United States the entire investment. The amount of the annual profit will be the factor

which in the last analysis will determine the time when the investment is fully amortized. It may appear to be good business to let the canal thus pay for itself, but there is another side to the question.

If the earnings of the canal are so regulated that they will meet operating expenses and interest on a bonded debt equal to the cost of the canal and no more, then the United States will be in the position of having loaned to commerce, as a permanent investment, a sum equal to the canal cost. The United States will be receiving interest on this investment. Apart from the benefits resulting to the country indirectly, the United States will be no better and no worse off financially than if the canal had not been built.

If, as an extreme case, it be assumed that the earnings are such that they will just meet operating expenses (including all replacement requirements) but nothing for interest and sinking funds, then the United States will be in the position of having donated for the benefit of the world's commerce a sum equal to the cost of the canal.

When a highway is constructed, when a harbor is dredged, when such works as the breakwater at San Pedro Bay, the breakwater at the mouth of the Columbia River, the South Pass at the mouth of the Mississippi River, the Ambrose Channel at New York harbor, and the many lighthouses on our ocean coasts, on the lakes and rivers, are constructed at government expense, the commerce which is benefited thereby is not taxed. The cost of these works is willingly borne by the country at large. There is no sinking fund to be provided. No interest on the investment is expected. Even the operating expenses come from the national or state treasuries. All this finds general acceptance as a matter of course. It is economically sound. The indirect return to the country is many times greater than the cost which has been incurred in the construction of such improvements, and no one objects to the wise expenditure of public funds for these purposes.

In what respect then does the Panama Canal as an aid to commerce differ from these works which are nearer home? In this only, broadly speaking, that in the case of all these other improvements, there is United States territory at one end, at least, of each business transaction which they facilitate, while the Panama Canal not only facilitates business between our own ports and between our country and foreign countries, but, also, in no small measure, the business carried on between foreign countries.

This fact needs no elaboration. It is patent. And due to this fact a different fundamental principle should find application than has so generally and properly been applied to the improvements which our nation and the several states and municipalities have made and are constantly making for the benefit of the public. This does not mean that we are to exact the "whole pound of flesh"—that we are to make

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the traffic pay for the canal. By no means. We should not even ask the traffic to return to us any part of the canal cost, but we may, in all fairness, ask for a small interest return in order that foreign shipping, engaged in trade between foreign countries, may not be relieved entirely of a fair contribution toward interest on the money invested in the canal.

In so far as the business having any United States port at one end is concerned, it would be not only proper, but desirable, to have the tolls arranged with a view to making no interest return upon the invested capital. Let the whole country, every section of which profits directly or indirectly, stand this part of the operating cost. But in the case of traffic through the canal with foreign ports at each end of the business transaction the matter is different, and whether the ships be under a foreign or under the American flag, the tolls should be somewhat higher, estimated perhaps as they would be estimated if the entire traffic through the canal were to yield a low interest rate on the investment.

Professor Emory R. Johnson, in his report as special commissioner on Panama traffic and tolls, addressed to the Secretary of War in 1912, passes lightly over these questions. He accepts the principle that "business prudence and political wisdom demand that the canal shall be commercially self-supporting, provided revenues large enough to enable the canal to carry itself can be secured without unwisely restricting traffic" and says "the annual revenue ultimately required to make the canal self-supporting will be about $19,250,000." In this sum there are included $3,750,000 for amortization of the government's investment in the enterprise. Professor Johnson says:

> In deciding what tolls shall be charged for the use of the canal, the fundamental question is whether a system of charges can be devised and levied that will ultimately yield about $19,250,000 per annum without unduly burdening American trade and without seriously limiting the ability of the canal to compete for traffic against the routes via the Straits of Magellan, the Cape of Good Hope and the Suez Canal.

It is gratifying to find that in a later paper read before the International Engineering Congress in 1915 by Professor Johnson, there is an apparent modification of the view expressed by him in 1912. He says:

> The government should resist this pressure [to lower the rate of tolls] until the revenues derived from the canal cover the annual operation and maintenance expenses and the interest on what it cost to build the waterway.

This is sound doctrine, if we accept interest to mean interest at a low rate, except only for the fact that the government might do well to give way to the pressure long before interest on cost is fully covered by the earnings.

Professor Johnson in his recent paper points out that if the rate of

tolls now established be maintained for ten years and if subsequent reduction be made with caution, it will be possible for the American people to secure revenues from the canal that will ultimately return to the United States treasury the sum that has been invested in the waterway. He leaves us in doubt, however, whether he distinctly advocates this course, saying only that

> This can be done without restricting the usefulness of the canal, and if this policy is followed out it will be possible for the United States, with less burden to the taxpayers of the country, to construct other needed works.

Against any policy looking to the recovery of the cost of the canal out of its earnings there should be strong protest. It can not be carried out without materially restricting the usefulness of the canal. It would be unwise and unfair to those who use the canal. It would put this government into the undesirable position of having entered upon a commercial venture for profit with unnecessary restrictions upon the world's commerce.

If Professor Johnson's prediction be accepted as fairly dependable the canal tolls as now fixed are too high and should be reduced at the earliest possible moment. It should be assumed that the commerce of the present day should be relieved from any unnecessary burden fully as much as that of the future.

If the cost of the canal must some day be returned to the United States by the users of the canal, let this occur, not in this generation, but in the future when the larger traffic will not feel an added charge as a burden.

In giving expression to these views no consideration has been given to the fact that for military purposes alone the canal is worth to the United States all that it has cost. There is special reason therefore for making the traffic charges lower than would be done if the construction of the canal had been determined by commercial considerations alone.

The proposition, sometimes advanced, that consideration should be given to the transcontinental railroads when canal tolls are fixed is without special merit. Their business is a matter apart. They are entitled to and will get adequate protection, but should not look to a high canal tariff as an aid in increasing their business. There is no obligation on the part of the American people to reduce canal traffic for the benefit of the railroads and their users, and it would be a mistake on the part of the railroads to make any such claim.

DARWIN

steamboat and the railway, the automobile and the aeroplane, America has done more than its share. But as the machinery of civilization becomes more complicated, we can no longer depend on isolated invention, but must undertake investigations requiring long preliminary training and complex adjustments. To a certain extent the need is met by the industrial laboratories which by aid of the patent office now conduct elaborate investigations. But the ideal solution of the problem is to pay men for the value of their services or to employ men to do the work for which they are most competent, and this can best be accomplished if the people, as a whole, will make the investment and reap the profits. In no better way can this be done than by the support of the scientific bureaus of the government and the establishment of experiment stations in each state.

An aristrocratic social system has in the past been more favorable than a democracy to the production of men of exceptional performance in science. A selected class, possessing inherited ability and inherited wealth, can supply a few men far surpassing in ability the average man and can give them opportunity and appreciation. But we may hope that as soon as the value of research in pure and applied science, and, it may be added, of production in letters and the fine arts, are widely understood, a democracy may have a wider field from which to select men of special ability and will provide adequate opportunity and rewards.

It would be interesting if we had a comparative study of the productivity

search in the mechanic arts and engineering, and the sciences, such as physics and chemistry, on which they are based. The agricultural interests have always had great influence on legislation and in this case they have led the way. It is to be hoped that research in the engineering sciences will now be equally encouraged by the passage of the Newlands bill, which appropriates $15,000 to each state and territory for conducting investigations in engineering and publishing the results.

Some scientific men may believe that more could be accomplished by the establishment of one great research laboratory or by granting the money only to institutions already distinguished for their contributions to science. There is, however, much to be said for initiating investigation in fifty widely scattered centers where work is already being done in agricultural science. It brings the value of research to the attention of the students of the college and the people of the state, and each station has the possibility of great development. In any case the passage of the bill as it stands is the most feasible method at present to extend research and will forward rather than interfere with other methods.

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WHEREAS in a democracy scientific research, which is for the general benefit and can not usually be sold to individuals, must be supported by the public;

WHEREAS a combination of national and state support and control is desirable in education and in research and its value has been fully proved by the land grant colleges of agriculture and the mechanic arts, established in the states and territories by the Congress in 1862;

WHEREAS there is in connection with each of those colleges an agricultural experiment station to which the national government appropriates annually $30,000 for agricultural research, the results of which have been of untold value to agriculture and to the nation;

WHEREAS experiment stations for the mechanic arts and engineering, including in their scope research in physics, chemistry and other sciences, would be of equal value to the nation and would repay manyfold their cost, and

WHEREAS at the present time attention is directed to the need of preparation for every emergency, and this can best be accomplished by the advancement of science and the ability of our people to meet new conditions as they arise;

Resolved that the Committee of One Hundred on Scientific Research of the American Association for the Advancement of Science earnestly recommends the passage of the Senate Bill introduced by Mr. Newlands to establish experiment stations in engineering and in the other branches of the mechanic arts in connection with the colleges established by the Congress in the several states and territories, with an annual appropriation to each of $15,000 for conducting investigations and experiments and printing and distributing the results; and further

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In so far as the apparent superiority of America in psychology is due to the fact that it is a new science, the promise for the future in other directions is but emphasized. We are providing opportunity for research work in all the sciences, and we may be confident that the ability exists and only needs the chance to exhibit itself. The war will so cripple the resources in men and money of the great nations of Europe that peculiar responsibility is thrown upon us. We may also hope that the lesson of the war to us will be that the best preparation for the future is the development of our educational and scientific institutions.

LISTER

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We record with regret the death of Sylvanus P. Thompson, the famous English physicist; of Carl Schwarzschild, director of the Astrophysical Observatory at Potsdam, and of E. Jungfleisch, professor of organic chemistry at the University of Paris.

The late Lady Kelvin has bequeathed to Glasgow University £5,000 for promoting research and the teaching of physical science in connection with the chair of natural philosophy, long held by Lord Kelvin. The decorations and medals conferred on Lord Kelvin are also given to the university.—The British Chemical Society has decided to publish portraits of the three past presidents, Sir Henry Roscoe, Dr. Hugo Müller and Professor Raphael Meldola, who have died during the past year.

At the annual spring meeting of the General Education Board $789,980 was appropriated for institutions and projects to which the organization contributes. The largest appropriation was for the medical department of Washington University at St. Louis, which received $250,000. This makes $1,000,000 given by the board to this institution toward a total of $1,500,000 for the purpose of placing the teaching of medicine, surgery and pediatrics on a full-time basis. Other appropriations were: Coker College, Hartsville, S. C., $50,000; Colby College, Waterville, Me., $125,000; Rockford College, Rockford, Ill., $75,000; further prosecution of educational researches, $50,000; Spellman Seminary, Atlanta, Ga., $20,000; Hampton Institute, $25,000; Tuskegee

WHO PAYS FOR THE PANAMA CANAL

By C. E. Grunsky, Eng.D.
One Time Member Isthmian Canal Commission

HAD the Panama Canal been constructed by private enterprise subject to rate regulation by the United States, it is safe to say that the owner would have been allowed earnings that would cover operating expenses, including the requirement of replacing all parts thereof as they go out of use, and also a reasonable return on the capital invested in the enterprise. There would have been no allowance for amortization of the capital unless in the special case of a term franchise and a purpose on the part of the United States to acquire the canal during the life of the franchise. On the assumption of perpetual ownership by private parties there would be no sense in allowing the investment to be reduced unless the United States should desire to become a partner in the enterprise to the extent of such reduction.

The American people, as owners, are accountable to the whole world for the management of this enterprise and should make themselves familiar with the fundamental principles which should control the establishment of the canal tolls.

Has the United States constructed the canal for profit?

Has the United States constructed the canal as an investment which is to yield a reasonable return on its cost?

Has the United States made the investment in the canal as a temporary investment which it will endeavor to recover from those who use the canal?

Can the United States afford to make such investments for the benefit of commerce without recovering interest on the investment?

The answers to these questions will guide the economist who fixes the tolls, and will give him his starting point.

If the net earnings of the canal, that is, earnings in excess of operating expenses, are sufficient to meet interest on a bonded debt equivalent to the cost of the canal and enough surplus to return to the United States in a fixed time, as, for example, 100 years, the cost of the canal, then, at the end of this time the United States will no longer be out of pocket anything for canal construction. The nation will be in the same position as though some one had made it a present of the canal. During this time at some regular or irregular rate those who have travelled through the canal, and those who have purchased the goods transported through it, will have returned to the treasury of the United States the entire investment. The amount of the annual profit will be the factor

which in the last analysis will determine the time when the investment is fully amortized. It may appear to be good business to let the canal thus pay for itself, but there is another side to the question.

If the earnings of the canal are so regulated that they will meet operating expenses and interest on a bonded debt equal to the cost of the canal and no more, then the United States will be in the position of having loaned to commerce, as a permanent investment, a sum equal to the canal cost. The United States will be receiving interest on this investment. Apart from the benefits resulting to the country indirectly, the United States will be no better and no worse off financially than if the canal had not been built.

If, as an extreme case, it be assumed that the earnings are such that they will just meet operating expenses (including all replacement requirements) but nothing for interest and sinking funds, then the United States will be in the position of having donated for the benefit of the world's commerce a sum equal to the cost of the canal.

When a highway is constructed, when a harbor is dredged, when such works as the breakwater at San Pedro Bay, the breakwater at the mouth of the Columbia River, the South Pass at the mouth of the Mississippi River, the Ambrose Channel at New York harbor, and the many lighthouses on our ocean coasts, on the lakes and rivers, are constructed at government expense, the commerce which is benefited thereby is not taxed. The cost of these works is willingly borne by the country at large. There is no sinking fund to be provided. No interest on the investment is expected. Even the operating expenses come from the national or state treasuries. All this finds general acceptance as a matter of course. It is economically sound. The indirect return to the country is many times greater than the cost which has been incurred in the construction of such improvements, and no one objects to the wise expenditure of public funds for these purposes.

In what respect then does the Panama Canal as an aid to commerce differ from these works which are nearer home? In this only, broadly speaking, that in the case of all these other improvements, there is United States territory at one end, at least, of each business transaction which they facilitate, while the Panama Canal not only facilitates business between our own ports and between our country and foreign countries, but, also, in no small measure, the business carried on between foreign countries.

This fact needs no elaboration. It is patent. And due to this fact a different fundamental principle should find application than has so generally and properly been applied to the improvements which our nation and the several states and municipalities have made and are constantly making for the benefit of the public. This does not mean that we are to exact the "whole pound of flesh"—that we are to make

the traffic pay for the canal. By no means. We should not even ask the traffic to return to us any part of the canal cost, but we may, in all fairness, ask for a small interest return in order that foreign shipping, engaged in trade between foreign countries, may not be relieved entirely of a fair contribution toward interest on the money invested in the canal.

In so far as the business having any United States port at one end is concerned, it would be not only proper, but desirable, to have the tolls arranged with a view to making no interest return upon the invested capital. Let the whole country, every section of which profits directly or indirectly, stand this part of the operating cost. But in the case of traffic through the canal with foreign ports at each end of the business transaction the matter is different, and whether the ships be under a foreign or under the American flag, the tolls should be somewhat higher, estimated perhaps as they would be estimated if the entire traffic through the canal were to yield a low interest rate on the investment.

Professor Emory R. Johnson, in his report as special commissioner on Panama traffic and tolls, addressed to the Secretary of War in 1912, passes lightly over these questions. He accepts the principle that "business prudence and political wisdom demand that the canal shall be commercially self-supporting, provided revenues large enough to enable the canal to carry itself can be secured without unwisely restricting traffic" and says "the annual revenue ultimately required to make the canal self-supporting will be about $19,250,000." In this sum there are included $3,750,000 for amortization of the government's investment in the enterprise. Professor Johnson says:

> In deciding what tolls shall be charged for the use of the canal, the fundamental question is whether a system of charges can be devised and levied that will ultimately yield about $19,250,000 per annum without unduly burdening American trade and without seriously limiting the ability of the canal to compete for traffic against the routes via the Straits of Magellan, the Cape of Good Hope and the Suez Canal.

It is gratifying to find that in a later paper read before the International Engineering Congress in 1915 by Professor Johnson, there is an apparent modification of the view expressed by him in 1912. He says:

> The government should resist this pressure [to lower the rate of tolls] until the revenues derived from the canal cover the annual operation and maintenance expenses and the interest on what it cost to build the waterway.

This is sound doctrine, if we accept interest to mean interest at a low rate, except only for the fact that the government might do well to give way to the pressure long before interest on cost is fully covered by the earnings.

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Vol. 3, No. 2 AUGUST, 1916

THE SCIENTIFIC MONTHLY

EDITED BY J. McKEEN CATTELL

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THE SCIENCE PRESS

LANCASTER, PA. GARRISON, N. Y.

NEW YORK: Sub-Station 84

Single Number, 30 Cents Yearly Subscription, $3.00

THE PROGRESS OF SCIENCE

ENGINEERING EXPERIMENT STATIONS IN THE LAND GRANT COLLEGES

On July 2, 1862, President Lincoln approved the act establishing the Land Grant Colleges of Agriculture and the Mechanic Arts, and on March 3, 1863, he approved the act incorporating the National Academy of Sciences. When the nation was stricken down with civil war it sought relief in science, on the one hand, establishing institutions for the scientific education of all the people in the arts of peace, on the other hand, recognizing exceptional merit in science and making the most distinguished men of the country the advisers of the government.

Now when the world is again infected by war more terrible than can be imagined in this one great nation which has escaped, we are naturally driven to think of "preparedness," and it will be well if this movement can be directed to making the nation strong through education and scientific research. At least three bills are before the Congress which are more important for the welfare of the country and its defense from foreign aggression, should that ever become necessary, than any enlargement of the army and navy. These bills would establish a national university, extend secondary education in industry and agriculture, and establish research stations for engineering at the colleges of agriculture and mechanic arts.

A national university at Washington, holding the same position toward the state and privately endowed universities as these hold or should hold to the colleges and schools of each state, would correspond with the establishment of the National Academy of Sciences during the civil war, but could be made far more effective in its influence on research and on the efficient conduct of the departments of the government.

The Smith-Hughes bill provides for the promotion of the vocational education of boys and girls of high-school age through cooperation of the nation and the states. There is appropriated for the first year $1,700,000 with an increment each year for eight years on condition that each cooperating state shall appropriate an equal sum. In the first year the sum of $200,000 is for administration and investigation, $500,000 for training teachers for vocational work, and $1,000,000 for payment of teachers, equally divided between agriculture, on the one side, and trade, home economics and industry, on the other.

Of special interest to scientific men is the Newlands bill establishing research stations in engineering, corresponding to the existing agricultural stations in the colleges of agriculture and the mechanic arts. These land grant colleges and their agricultural research stations have been of incalculable value to education, to agriculture, to the states and to the nation. They have been largely responsible for the establishment and development of the state universities. The land grant colleges and the institutions of which they are a part received in 1914 from the United States $2,500,000; from the states and from other sources over $30,000,000. They have 9,000 instructors and 105,000 students.

By the Hatch act of 1887 and the Adams act of 1906 the sum of $30,000 a year is appropriated for research in agriculture in the experiment stations. The colleges have more students of mechanic arts than of agriculture, but there is no similar provision for re-

search in the mechanic arts and engineering, and the sciences, such as physics and chemistry, on which they are based. The agricultural interests have always had great influence on legislation and in this case they have led the way. It is to be hoped that research in the engineering sciences will now be equally encouraged by the passage of the Newlands bill, which appropriates $15,000 to each state and territory for conducting investigations in engineering and publishing the results.

Some scientific men may believe that more could be accomplished by the establishment of one great research laboratory or by granting the money only to institutions already distinguished for their contributions to science. There is, however, much to be said for initiating investigation in fifty widely scattered centers where work is already being done in agricultural science. It brings the value of research to the attention of the students of the college and the people of the state, and each station has the possibility of great development. In any case the passage of the bill as it stands is the most feasible method at present to extend research and will forward rather than interfere with other methods.

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of different nations in science, which would determine how it has changed in quality, quantity and direction from period to period, and how far it has depended on natural ability and how far on social institutions. There is some basis to assume that the smaller European nations, Switzerland, Holland and the Scandinavian countries, have done remarkably well, that France has fallen behind Great Britain and Germany, that Great Britain has had the greatest number of men of exceptional performance, that Germany has produced the largest number of competent investigators and the best organization for research.

There are here reproduced photographs of four plaques which have been unveiled in Westminster Abbey, representing Darwin, Wallace, Hooker and Lister. They are fit representatives of the great men who gave distinction to Great Britain in the Victorian era. Of those men only Hooker held a scientific position, and he too is typical of the aristocratic system, for he inherited not only his ability, but also his wealth, his title and the directorship of the Kew Botanical Gardens from his father. Darwin is particularly notable as a representative of aristocratic and individualistic genius. He came from a family line manifesting great ability and having ample wealth; he married a wife from a similar line and transmitted to his children both ability and wealth. He filled no position but did his work while living as a country gentleman.

It is doubtful whether again we shall look on men like these. In Germany

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also there have been distinguished leaders, but, on the whole, the contribution of that country to science has come from the large number of individuals engaged in scientific research at the universities. In the past the United States has not produced scientific leaders comparable to English scientific men of the nineteenth century or numbers of able investigators equal to those of Germany. But it may be that we have been gradually assuming a position in which we are contributing to the advancement of science on terms of equality with these nations. If the science with which the writer of this note is concerned may be taken as an example, it may be claimed that we produced in William James the greatest contemporary psychologist, and we appear to have more competent workers in psychology than any other nation. "Who's Who in Science" an English publication, selects for biographical sketches psychologists as follows from the different nations: United States, 95; Germany, 37; Great Britain, 30; Austria-Hungary, 13; France, 12; Italy, 12; Switzerland, 10; Russia, Holland and Norway, each 6.

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LISTER

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Institute, $25,000; Morehouse College, Atlanta, $5,000; Fisk University, Nashville, $5,000; Mayesville Industrial School, Mayesville, S. C., $1,000; equipment of normal schools for negroes in North Carolina, $4,050; equipment of county training schools for negroes, $10,000; support of professors of secondary education, $34,130; state agents for white rural schools, $40,800; state agents for negro schools, $34,500; educational research in New Hampshire, $5,500; farm demonstration work in Maine and New Hampshire, $8,500.

ON the occasion of his seventieth birthday on March 16, 1916, Professor G. Mittag-Leffler and his wife made a joint last will and testament of peculiar significance in the domain of science. Extracts from this will have recently been published by Professor Mittag-Leffler in a pamphlet, so that the features of the document are now public property. By the terms of the will there is founded a mathematical institute to bear the name of the donors, which institute is to be housed in their villa at Djursholm, Stockholm. The institute is to be fully established at the death of the donors, and is to consist of the villa in question, the mathematical library of Professor Mittag-Leffler, and a fund for the encouragement of pure mathematics, particularly in the four Scandinavian countries, Sweden, Denmark, Finland and Norway, but more especially in Sweden. The library is to be open to all mathematicians. Certain financial assistance is to be given to those who show genuine aptitude for research and discovery in the domain of pure mathematics. There is also provided for the bestowal of medals and of prizes in the form of sets of the *Acta Mathematica*.

A SECOND relief expedition is to be sent out from the American Museum of Natural History and the American Geographical Society in the hope of rescuing Donald B. MacMillan and the members of the Crocker Land Expedition sent out in 1913 by the American Museum of Natural History, the American Geographical Society and the University of Illinois. The party is believed to be several hundred miles northwest of northern Greenland. The first relief expedition is frozen in at Parker Snow Bay, 150 miles south of Etah. The second expedition will try to join forces with the first and then proceed to Etah. The steamship *Danmark* has been chartered for the trip, and the sum of $11,000 has already been pledged—$6,000 by the American Museum and its friends and $5,000 by the American Geographical Society.

Vol. 3, No. 2 AUGUST, 1916

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THE SCIENCE PRESS

LANCASTER, PA. GARRISON, N. Y.

NEW YORK: SUB-STATION 84

SINGLE NUMBER, 30 CENTS YEARLY SUBSCRIPTION, $3.00

THE SCIENTIFIC MONTHLY

AUGUST, 1916

CHANGING CONDITIONS IN THE KENTUCKY MOUNTAINS[1]

By B. H. Schockel
STATE NORMAL SCHOOL, TERRE HAUTE, IND.

THIS summary of changing conditions in the plateau of eastern Kentucky is based upon a month's field work, supplemented by previous and subsequent studies. The order of treatment is as follows: an introductory view of the topography, surroundings and settlement; the changing conditions with respect to the chief natural resources; manufacturing, transportation; the people, with reference to their numbers, distribution and condition, their institutions, and their customs and habits; the future.

Topography and Surroundings

Eastern Kentucky is a part of the Cumberland Plateau, and consists of 35 counties with an area of some 12,943 square miles, that is, about one third of Kentucky. It is a part of the Southern Appalachian Highlands. To the east of it are the parallel ridges and valleys of the Greater Valley of the Appalachians; to the west is the Blue Grass region. The top of the plateau was an old plain with low hills on it (a part of the Cretaceous Peneplain, with monadnocks) and sloped gently westward in Kentucky from an elevation of about 2,000 feet to a height of 1,200 to 1,500 feet. Since then this plain has been so thoroughly dissected by streams, in pattern like the branches of a tree, that probably not more than 4 per cent. of the land is level (topographic stage of mature erosion by dendritic drainage), the valleys being from 500 to 800 feet deep with narrow bottom lands, and the tops of the ridges averaging in many instances from 10 to 50 feet in width. The ridges, locally known as mountains, in general bear on their shoulders and crests hardwood forests sprinkled with conifers. Most of the lower slopes are cleared. From the top of Pine Mountain the Kentucky country appears to be a billowy wilderness. One can not see any valleys nor any sign of life; but beneath those forested waves are sylvan slopes to enchant one, and a sinister labyrinth of gashed valleys to grip one in mountain poverty.

[1] Illustrations by the author.

Owing to the topography the roads are serpentine; since the bed rock is of shale and friable sandstone chiefly, good road material is scarce; furthermore, the people are poor, and what we thoughtlessly term shiftless and ignorant; therefore, their highways are in a most wretched condition.

FIG. 1. BIRD'S-EYE VIEW OF THE KENTUCKY MOUNTAIN REGION, based upon the Kentucky Geological Survey and the topographic maps of the U. S. G. S. The extent of Pine Mountain shown is about 90 miles. The key to the map follows: 1, Blackie; 2, Buckhorn; 3, Cumberland Gap; 4, Cumberland Mountain; 5, Cumberland River; 6, Greasy Creek; 7, Hindman; 8, Jenkins; 9, Levisa Fork, Big Sandy River; 10, Line Fork; 11, Middlesboro; 12, Middle Fork Kentucky River; 13, North Fork Kentucky River; 14, Oneida; 15, Pine Mountain; 16, Pine Mountain Postoffice; 17, Pineville Gap; 18, Pound Gap ("Trail of the Lonesome Pine"); 19, Prestonburg; 20, Red River; 21, South Fork Kentucky River.

SETTLEMENT

In the sixteenth century, James I. introduced Scotch settlers into northern Ireland, who became the Scotch-Irish. Some of them emigrated to America; and their descendents, augmented by English, native

Irish, Pennsylvania Dutch, and others, formed the van of the 300,000 frontiersmen who passed through Cumberland Gap, 1775–1800, to settle in Kentucky.

Some of these found a home in the plateau region, which offered clear springs, magnificent forests, abundant game, and good valley land sufficient for that first generation of hunter-farmers. No one could have foretold then the coming of canal and railroad.

The first permanent settlements in the Kentucky mountains were made in the decades 1780 to 1800. Filson's map of Kentucky (1784) shows "settlements" on Rockcastle River, the Upper Louisa Fork, and a fork of Red River. By 1800 the population was 7,964, which was about four per cent. of the population of the state; it is now about 600,000, which is about twenty-five per cent. of Kentucky. Genealogical records of this people are utterly lacking. Their names and survivals in customs and language point to English and Scotch-Irish ancestry in general, although a few German and Huguenot names are found.

Between 1800 and 1840 the mountain region was an integral part of the state for various reasons. Four interstate, transmontane routes traversed the plateau in leading from the Ohio and the Blue Grass settlements on the west to the Big Sandy and Kanawha region on the east, and thus on to the tide-water communities. The plainsmen bought lean cattle in the Blue Grass and sent them in droves of from 200 to 300 through the mountains to the Potomac, where they were fattened and sold in Baltimore and Philadelphia. Large droves of hogs followed the same routes. Furthermore, the hog and cattle drivers bought corn at the homes of the mountain people and brought news from the outside world, thus binding the Kentucky people somewhat closely together. Also, because the Kentucky interstate commerce passed through the mountains, the slender state appropriations for roads were impartial, the mountain counties being favored equally with the lowland.

But between 1830 and 1850 the four interstate roads declined gradually to a wretched condition and state of non-use; for the Blue Grass and Ohio regions were finding other routes to market, by use of steamboats, etc. Therefore the mountain counties lost their market and received little outside help for roads. As a result, these peoples, who have never been able to travel freely among themselves within their mountains, have since about 1845 suffered the further handicap of being cut off from the outside world, and have lived in surprisingly complete isolation. Presently the civilization of the rest of the Americans changed, and they became "foreigners" to the mountain folk. Thus the mountaineers have lived isolated by topography and social antipathy.

During the civil war thousands of the mountaineers, whose ancestors had fought in the revolution and the war of 1812, joined the Union army and received a practical education. Some received similar train-

FIG. 2. SOUTH FORK KENTUCKY RIVER NEAR BOONEVILLE.

ing as soldiers of the south. After the war many returned home. But the growth of the formal education and the broader outlook, both of which were stimulated by the war, has been slow.

In 1878, Shaler, of the Kentucky Geological Survey, saw in the eastern, and then most inaccessible portion of the region, men hunting squirrels and rabbits with old English "short-bows" and wrote:

> These were not the contrivances of boys of to-day but were made and strung, and the arrows hefted, in the ancient manner. The men, some of them old, were admirably skilled in their use; they assured me that, like their fathers before them, they had ever used the bow and arrow for small game, reserving the costly ammunition of the rifle for the deer and bear.

Recently outside capital has begun to develop the coal and timber resources of the region, a fact which is bringing about many changes in the mountain country, and that rapidly. As a result, the inhabitants are facing the crisis brought about by the sudden mingling of a primitive people with the exploitative phase of modern civilization.

CHANGING CONDITIONS

We shall now turn to the changing conditions within the mountains, and consider the natural resources, first of all, the mineral wealth.

Mineral Resources

At an early period iron and salt within the region were the source of considerable traffic, but not now. Oil, gas and clays, although in progress of exploitation for the past two decades, do not promise to become important.

Coal is the chief mineral resource of the region. The seams occur in every county, increasing in number and thickness towards the south-

east and reaching their climax in the Black Mountain region. The layers are favorably disposed for mining, except in the Pine and Cumberland mountains, where complex structure renders mining difficult. The coal is bituminous, the most desirable varieties being as follows: Cannel, found in limited basins throughout the field; coking, appearing in large amounts only in the vicinity of Pound Gap; and high-class steaming coals, occurring in quantity in the southeastern counties and at a few places along the western margin.

Coal was exported in 1827, probably earlier; but until the railroad came, the output was insignificant. Though production is rather smal' at the present time, and limited to a few mines scatteied along the railroads, the region is beginning to become an important coal center.

The first extensive exploitation began in the region about Middlesboro, in 1892. At present most of this coal is shipped south. Some two years ago a branch of the L. & N. railroad was pushed up the North Fork Kentucky River to Hazard, and extensive coal mining began. Hazard is now (1915) in its ugly duckling stage, has a population of about 2,000, boasts one of 3,500, and altogether is a scar upon the beautiful landscape, like a "boom" town of the west. But the most spectacular development is taking place at Jenkins, on the headwaters of Elkhorn Creek, at the foot of Pound Gap, Pine Mountain, known in literature as "The Trail of the Lonesome Pine." Eighteen months ago a branch of the B. & O. railroad reached the site, where a few months prior there had been but one mountain cabin. Jenkins now has brick buildings three stories high; a great power plant; palatial residences; a splendid hospital; a concrete dam causing an artificial lake, upon which are pleasure boats; and a town reservoir, into which spring water is filtered from the mountain. Indeed it is growing as fast as Gary,

FIG. 3. CUMBERLAND GAP.

FIG. 4. FARMS AND FOREST NEAR BOONEVILLE.

Indiana, in its early days. Most of this coal is shipped across Indiana to Gary.

Forest Resources

The virgin forests were splendid. But since an early day, lumber has been shipped to an outside market; therefore the timber area has been reduced, and, although it remains the chief source of wealth, the end is almost in sight. About thirty per cent. of the region was in wood in 1910, not all of which was primeval.

The mountaineer's way of lumbering is to cut a few choice trees and "snake" them down to the creek, where, as logs, rafts or railroad ties, they await the coming of the flood, or "tide," to be floated down stream. Thus a man can produce ten ties per day, for which this summer, near Beattyville, he received thirty-eight cents apiece. But lumbering corporations are beginning to attack the two remote corners of the Southern Appalachian Highlands, the Smoky Mountains and the Kentucky Plateau; and after the onslaught, in which stumps three and one half feet in diameter are left to rot, the hills are gaunt with slash, or black from resultant forest fires. Consequently increased erosion is resulting on the slopes, with augmented harmful deposition on the flats below. Furthermore, within and below the plateau, the streams increasingly are characterized by short periods of flood, and long intervals of low stage. Also, the supply of drinking water and water power is becoming less constant.

Most of the timber is owned by outside capital. The United States government is seeking to buy wooded land for forestry, having completed the first step in 1914, when it purchased the 60,000 acre Biltmore estate, near Asheville, N. C.

A passing forest industry is the digging of ginseng and other roots.

The normal market price for the first is five dollars to seven dollars per pound, but now, owing to the war, the price has fallen. I came upon one old man and his wife, digging "sang" in the woods, who stopped to talk for an hour and wanted to know why it is that the Chinese can not live without the root, and what would happen to that people when the supply shortly would give out in America, but who then consoled themselves with the thought that probably the Chinese have enormous amounts of it stored away in anticipation.

Animal Resources

Wild game is becoming surprisingly scarce, due to over hunting and lax observation of hunting laws. In general the supply of fish is low, some causes being: Dynamiting and seining, lack of restocking, and inconstant and turbid streams resulting from deforestation. What little meat is eaten is chiefly swine and chicken. Sheep continue to suffer from exposure and dogs, and are decreasing in numbers. Beef is walked to market to obtain cash with which to pay taxes. Cattle raising is becoming more important. The Ayrshire stock is giving way to a fine short-horn type of cattle, owing to the opening of stockyard cattle markets, as at Mt. Sterling. The mountain mule and pony are being displaced by larger types. Mules are increasing, while horses are decreasing. Goats suffer from the rough, wet, winter climate.

The development of pasturage for live stock would prove to be a lasting advantage. Timothy is the chief forage crop; clover is second. A diminutive Japanese clover has filtered into the mountains, and takes possession of deserted fields. It is good for grazing, but it is too small to be cut.

FIG. 5. LOGS AWAITING HIGH WATER, "HIGH TIDE," IN THE SOUTH FORK KENTUCKY RIVER, NEAR ONEIDA.

Agriculture

About 80 per cent. of the land is in farms, of which 45 per cent. is improved, and 23.5 per cent. in woodland. The average size of the farm is 85.7 acres, of which about 39 acres are improved (Kentucky, 85.6, 55.4; Indiana, 98.9, 78.6). Twenty-four and a half percent. of the farms range in size from 50 to 99 acres; 19 per cent. from 100 to 174 acres; and 18.5 per cent. from 20 to 49. The average value of all crops per farm in 1910 was $310.70 (Kentucky, $536.20; Indiana, $947.60). The average value of implements and machinery per farm in 1910 was $32.3 (Kentucky, $80; Indiana, $190). About 6.6 cents worth of fertilizer was used per improved farm acre in 1909 (Kentucky, 8.7; Indiana, 12.8).

The total value of all crops in 1909 was 24.8 million dollars, of which cereals amounted to 12.2 million, vegetables 3.8, hay and forage 1.1, and fruits and nuts 1.1. The total area in cereals was 921,538 acres, of which corn constituted 841,744 acres; oats, 39,341; wheat, 36,403; rye, 1,579; and barley, 510. Some 21,397 acres were devoted to potatoes, 5,673 to sweet potatoes and yams, and 10,713 to edible beans (a staple food in the mountains). Sorghum was raised on 21,970 acres, and hay and forage on 162,944 acres. There were 1,825,895 apple trees out of a total of 2,425,047 fruit trees. Peaches ranked second to apples.

The average production of corn per acre in 1909 in the region was 18.7 bushels; in Kentucky, 24.2; in Indiana, 40. The corresponding figures for wheat were 9.9; 12.8; and 16.3. Similar data for potatoes were 76.6; 91.8; and 99.4. The respective figures in tons of forage per acre were .8; .9; and 1.2.

The shale soil, which is most common, is fairly fertile, and produces good crops of corn under good cultivation, on gentle slopes. The chief causes for the low productivity are steep slopes, poor cultivation and lack of crop rotation. The shale soil washes less than almost any other soil under like circumstances. The wonder is that the soil produces as much as it does.

A few years ago Berea College, with the help of the United States government, employed a special investigator and demonstrator to work with the mountain farmers within reach of Berea. The success was such that a number have been appointed in other localities. About Berea, heavy breaking plows are replacing the one-mule plow, and the disk harrow is appearing in the mountains. More than twice as many shallow cultivators as single-shovel and double-shovel plows were sold in Berea last spring. The practise of sowing cowpeas and rye for forage and turning under is spreading, as is the use of commercial fertilizer. Crop rotation is displacing the fallow system.

Further education in agriculture is being given at the missionary and settlement schools, as at Oneida, Hindman, Buckhorn and Blackie.

But agriculture in the interior of the region is yet primitive, and improvements are slow in penetrating. A common sight is corn growing among girdled trees.

The few truck gardens which are being introduced about the settlements and mining and lumbering camps are giving favorable results. Of course, each farm has its little garden for home use.

Naturally, the region is a splendid fruit country, especially for apples; but spraying is unknown, and the stock has degenerated. Therefore the trees bear abundant crops of gnarled, sour fruit. One mountain woman told us to take as many apples as we wished, since they were of no value except to sharpen the teeth on. Often apples are sold for ten cents per bushel, are given away, or rot, on account of poor transportation.

Manufacture

Turning now to manufacturing within the region, we note that it always has been meager, primitive and for local use, except in the case of salt in the early days.

In 1901 Bell and Boyd counties contained 172 manufacturing establishments, with an aggregate capital of $5,201,489, an amount which was more than one half of that invested in manufactures in all the thirty-five counties in 1910. The cause for the emergence of these two counties is the recent growth of Ashland and Catlettsburg on the Ohio River, and Middlesboro near Cumberland Gap, a local supply of coal being the factor in each case. Hazard and Jenkins soon will rank as manufacturing cities.

The status of manufacturing for 1900 is indicated in the following table:

	Establishments	Cap. Per Establish.	Men 16 Yrs. and Over	Women 16 Yrs. and Under	Children Under 16	Capital	Value of Products
Kentucky Mts.	1,156	$7,221	4,853	44	85	$ 8,347,993	$ 11,993,195
Kentucky	9,560	10,886	51,101	9,174	2,687	104,070,791	154,166,365

The mills are small and driven in general by water, animal, and hand power. Machine-made goods from the outside have supplanted the linsey-woolsey cloth, counterpanes and baskets made in the cabins. But, recently, the missionary and settlement schools have begun to sell such goods outside of the mountains for the people, to supply cash, and therefore the industries are reviving, in part. The W. C. T. U. Settlement School at Hindman, for example, sold $1,800 worth of such goods in 1914.

Distilling always has been a widespread industry in the mountains, since thereby corn, the chief crop, is converted into a product which can be marketed with profit, and since the custom has been inherited. Illicit

distilling increased greatly after the imposition of the liquor tax of the Civil War. In 1877 the government began to suppress "moonshining" in the region. By 1882 the supremacy of the law had been established. But in 1894 the liquor tax was increased from ninety cents to one dollar and ten cents, which resulted in increased "moonshining." The counties have been voted "dry," which encourages the illicit traffic. About the coal-mining centers, "blockading" is increasing greatly, the whiskey being brought to town under vegetables and in milk cans. Our mountain guide in the saddle of Pound Gap pointed down the "Trail of the Lonesome Pine," saying: "We can go right down there into Virginia and get all the spirits we want. I know where there is a still less than a mile away. There are a lot of 'em stuck 'round hereabouts in the rocks and the mist." One morning a strange young man, not from

FIG. 6. MOUNTAIN FARM, AND HOME WITHOUT WINDOWS.

Kentucky, boarded our train at a small station not far from the land of "Kingdom Come" and "Hell fer Sartin," and became my seat-mate. He had dark circles about his eyes, and otherwise looked tired. As he did not inform me as to his identity it is safe to recount his story. He gained the confidence of a mountain man and received a letter of introduction, which he presented to a second mountain man after walking some twenty miles up a certain creek. This man kept the letter, took him up a side branch and turned him over to a third mountaineer. This one led him to a cove and told him to "go straight ahead!" which he did. Presently he was standing in the door of a "moonshine" still, and three men faced him, their revolvers on a rude bench. After stating that his business was merely one of curiosity, and after answering a host of questions put sharply, he was required to drink some of the liquor. Then he remained with the men for an hour, talking with them and watching them at work. Upon leaving he was offered a gallon of

liquor for friendship's sake. But he could not carry that much; therefore they put a quart bottle into his pocket, telling him "Good-bye! Whinever you want some good liquor, or your friends, let us know. We make pure stuff. No 'dultering here." He stumbled along until about eight o'clock that night and came to a mountain town of twenty houses, having covered thirty-five miles that day. The story concerning the night and the next morning will not be told, lest it cause resent-

FIG. 7. A "DEADENING" CORNFIELD OF AN "UPRIGHT" FARM.

ment in that little town. Now it had happened that three days before, my comrade had lost, in this same general vicinity, a purse containing in all $110, whereupon we had trudged back down a mountain and had found the finder, who had gladly restored it to us, and indeed, who had told several people of his discovery, thus hoping to find the owner. Therefore I was in no mood to judge the "moonshiners" harshly, even though the quart bottle was shown to me.

Transportation

I wish I could adequately emphasize the fact that transportation is the basic problem of the region. Poor communication within it h-

influenced greatly every phase of life always, and bad connections with the outside have isolated the country since 1850. Of a total of 17,432 miles of road, there were within the entire region, in 1904, 83 miles surfaced with stone, and four miles with gravel. The present wagon freight is said to be about 44 cents per ton-mile. The average haul for a load of cross ties is from eight to ten miles, and about eight to twelve ties constitute a load. Logs delivered at the railroad for twenty dollars

FIG. 8. A PRIMITIVE MOUNTAIN HOME, NEAR BUCKHORN. THE TOP OF THE "MOUNTAIN" IS ABOUT 500 FEET ABOVE THE HOUSE.

per load are said to consume sixteen dollars in transportation. At a coal shaft mined by two mountaineers near Boonville, good cannel coal sells for seven cents per bushel. The cause is poor transportation. From Buckhorn to the railroad is eight miles. A team will make this trip for four dollars in good weather. The charges in this case are about 88 cents per ton-mile. The average cost of transportation in the United States by wagon is 23 cents per ton-mile.

The old law that every man must work on the roads six days annually is enforced feebly. By a statute passed in 1894, road taxes can be levied by the county and a road commissioner appointed. But this new

law is proving a failure in the mountains and is giving way to the old custom because the mountain county is too poor to pay the commissioner's salary, and because the mountain man may pay the tax in work, a fact which introduces again the old problem of road-work enforcement. Our venerable host at Booneville, formerly a judge, although deploring greatly the lack of education in his county, insisted that the most pressing need of his people is an outlet for their produce. "It used to be thirty miles to the railroad," he explained. "Now it is only ten. But the road leads over a mountain, and is full of chuck holes. In the spring time, when our heavy traffic must be carried on, the wheels sink axle-deep in the holes. If only we had an outlet to market." In 1904 the total expenditures upon the highways in a number of rugged mountain counties amounted to about $24 per mile. The average expenditure for the state, much less rugged and therefore requiring relatively smaller expenditures, was, nevertheless, $43.57. The history of the mountain roads emphasizes the inability of the people to provide themselves with efficient highways, and manifests the great need for outside help, state or federal. In general, road material would have to be imported at great expense. The costs of roads steadily increase as the forest retreats towards the headwaters.

In 1907 the United States Department of Public Roads as an object lesson built and macadamized in Johnson County, 5,780 feet of road, and constructed through Cumberland Gap, 12,300 feet of macadam pike, and graded 900 feet more, at a total cost of $7,050 per mile. This work demonstrates again that the construction of good highways in the mountain region, while possible, cannot be done without outside help. Besides the government routes there is a short stretch of macadam road (one to twenty miles) in five marginal counties, of which, however, Boyd County alone lies strictly within the mountain region. The coal company at Jenkins has surveyed and built six miles of well-graded dirt road connecting Jenkins and McRoberts. Owing to the enforcement of the road laws in Knott County, a fairly good ungraded dirt road extends thirty miles between Hazard and Hindman. Immediately west of Pine Mountain in Leslie County, no wagon roads were attempted till 1890, and few exist now.

Before the advent of railroads, highway improvements were negligible, but the past twenty years have seen progress. Numerous stretches of road, eight to ten miles in length, afford somewhat fair transportation for wagons to the railroads. Where the development of coal and timber has increased the wealth of the community greatly, substantial bridges have been built. Progress has been slowest in the rugged, extreme southeastern section of the region, even though railroads have begun to penetrate. There the old-fashioned English saddle and the sleds drawn by oxen are still in use.

Except for lumbering, the streams are used but little. The North.

Middle and South forks of the Kentucky River penetrate into the interior. They join at Three Forks, near Beattyville. Thence to Carrolton are 350 miles of good waterway. In 1853 some five locks we completed by Kentucky at a cost of $4,000,000, which assured good navigation for 300-ton steamers for a distance of over 100 miles. The federal government made improvements at the close of the Civil War. Since then the waterways have been declining. In 1887 there were passing Three Forks annually, 50,000,000 feet of lumber, in logs.

Railroad building began in 1856, but made no headway until between 1870–90. The progress has been slow and confined to marginal counties until recently. Within the past five years a line has penetrated the North Fork Kentucky River to McRoberts, a few miles west of Pine Mountain, and up the Poor Fork of the Cumberland River, by way of the gap at Pineville. The railroads have been built for the coal and lumber, and not primarily for general traffic. Since the advent of railroads, the conditions which have made possible "the mountaineer" have been passing away.

But in general the region is still landlocked. And the brutal truth is that as long as it remains landlocked but little improvement on a large or permanent scale can be expected.

Population

It is in order now to summarize the changing conditions among the people of the mountains. In 1910 the total mountain population was 561,881, representing an increase of 18 per cent. over that of 1900 (Kentucky: 2,289,905; 6.6 per cent.). Figs. 9 and 10 show the growth in population in Kentucky and the mountains since 1860. There was an average of 43.4 people per square mile in 1910 (Kentucky, 56.9; Indiana, 74.9). The density is greatest along the main river routes and in mining sections. The people continue to be distributed as clans in valleys, which are surprisingly heavily populated. Of necessity the people depend upon the lower slopes of the hills as much as upon the limited bottom lands, their "shoe-string farms" being found strung along little gullies as well as in broader valleys. A few farms are on the mountain sides, especially on benches or "coves" of somewhat gently sloping land, formed above some massive sandstone ledge. The average size of the mountain family is about 5.2 (Kentucky, 4.6; Indiana, 4.1). The rural population increased 17.1 per cent. in the last decade (Kentucky, 4.2 per cent.). There was no urban population (people living in towns of 2,500 or more) in 1870. In succeeding decades, as Ashland and Middlesboro developed as centers of coal mining, it numbered 3,280; 7,466; 17,428; and 24,004. These two cities are unique in the region in having a population greater than 5,000; but they soon will be joined by Jenkins and Hazard, about which coal mining is developing rapidly. In 1910 less than one half of one per cent. of the

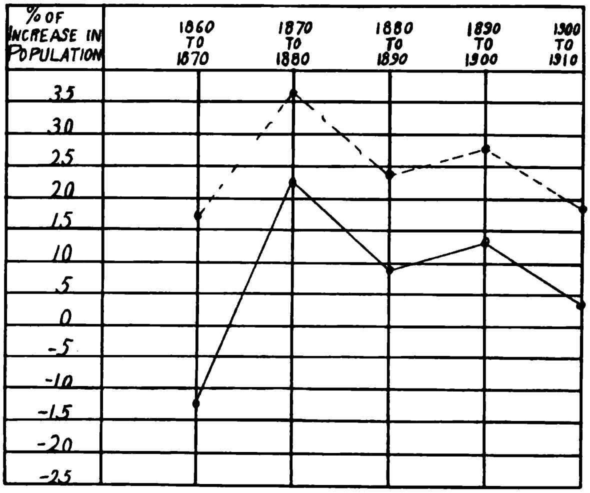

FIG. 9. GRAPH SHOWING THE PER CENT. OF INCREASE IN POPULATION IN THE MOUNTAIN REGION (BROKEN LINE) AND IN THE REST OF THE STATE (FULL LINE).

total population was foreign born. These people were chiefly skilled miners from England, Sweden, Germany and Switzerland, who drifted in by way of Pennsylvania. In seven counties there were no farmers of foreign birth; and in only one county did the foreign born exceed 21. Recently, Southern Europeans have begun to come, particularly Italians

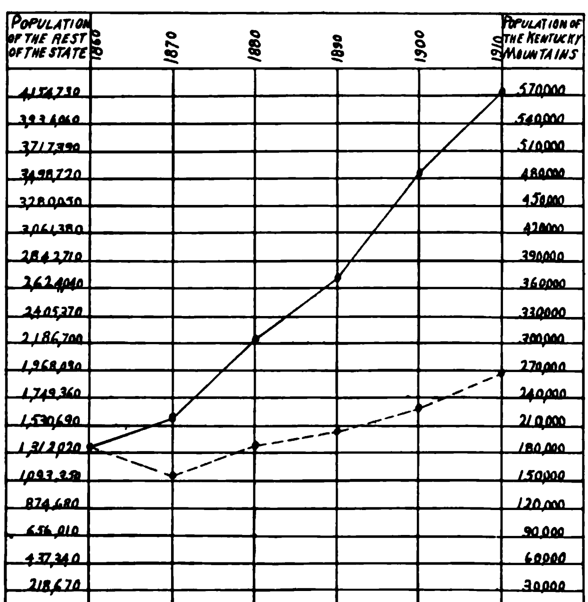

FIG. 10. GRAPH SHOWING THAT THE INCREASE IN POPULATION OF THE REST OF THE STATE (BROKEN LINE) SINCE 1860 HAS NOT KEPT PACE WITH THAT OF THE MOUNTAIN REGION (FULL LINE). Had it done so the population of Kentucky in 1910 would have been over four and one half millions.

FIG. 11. THE GENTLE SLOPE, DUE TO AN OUTCROP OF SHALE, HAS MADE IT POSSIBLE FOR THIS MOUNTAIN HOME TO BE RELATIVELY PROSPEROUS. Near Hindman.

and Hungarians. By 1920 the number of foreign born will have increased greatly. In 1900 about two per cent. of the population were negro, and in 1910 two and one half per cent. In three counties there were no negroes; and in sixteen, less than 20.

The problem presented in the region by the rapid increase in population with no corresponding increase in foodstuffs probably is not greatly overdrawn in the following statements by a mountain graduate of Berea College:

> The pioneer of 1850 who sat in his front door watching the deer rove the unbroken forest, to-day sitting in the same place can see acres of spoiled farm land. A few years ago the people produced enough on their farms to support themselves. To-day one half of the food consumed is brought in by the merchants. Twenty-five years ago our hillsides produced forty bushels of corn per acre. To-day the average yield of corn per acre is a little less than twenty-five bushels. (In 1909 it was 18.7 in the region.) The independent farmer of yesterday has been transformed in the last few years to a man dependent upon his staves and ties for support. Now, his farm is grown up in bushes, and his timber supply is almost exhausted. . . . Such is the condition of a vast number of our mountain farmers.

There is an emigration of the mountain families, or of sons and daughters, particularly from the marginal counties, where a fringe of mountain territory has been put in touch with outside progress and humanity, and where mountain peoples are buying adjacent lowlands. Some are moving to Oklahoma and the far west. This in part accounts for a decrease in the population of five counties. Not all of the emigrants become Lincolns (he was of their stock), though the mountain mind, not having been subjected to the specializations of our age, tends to remain fluid. Indeed many leaders in the mountains, including Mr. J. C. Campbell, secretary of the Southern Appalachian division of the

Russell Sage Foundation, have informed me that the great majority of these emigrants who go untrained into the economic struggle of the outside world fare poorly. I was strikingly reminded of this fact in a mountain pass by my guide, who said that one of his cousins has gone to Arkansas and has written for him to come also. My man informed me that he is "athinking about it in his mind." Sometimes he thinks he will go. "Does that land produce there?" he queried again and again. "Would it feed a man? What is the lay of the land? How high are the mountains, and the color of the soil, is it red? Some tells me as how it is a clay soil. But clay soil won't produce well. Hereabouts hit won't produce much more'n grass." I couldn't make him realize that far away Arkansas is a large state with varied soils and topography. I felt hopelessly that when I spoke of the tracts of level land in the country of promise, he thought of it in terms of the few acres of bottom land of his home hemmed in by mountains, for "isn't it true that that's what the world is, mountain and slope? Some tells me to go; some tells me not. I might go and find that the land wouldn't produce. I'm afraid that if I go, my kin 'll be het up about hit. Then if the soil won't produce, I'd have to come back, an' them set agin me."

Public health is not as good as might be expected at first thought. The situation has been summarized by Miss Verhoeff (in "The Kentucky Mountains") as follows:

> **Endurance and muscular strength are common, but a strong constitution is exceptional. Bad housing and sanitation, ill-cooked and insufficient food, exposure to weather, and . . . poverty, have had their detrimental effects, which have been augmented by a close intermarriage of families and by an inordinately large use of liquor.**

FIG. 12. APPLES FROM AN ABANDONED MOUNTAIN FARM. Poor transportation makes their marketing impossible.

In general the mountain man is quicker than the Indiana plainsman, but not as strong. A month's field work did not bring to my notice any of the storied giants of the hills, though there probably are some. Not all of the people are lank.

About two generations ago trachoma penetrated into the mountains, and is spreading rapidly, despite the efforts of the state and settlement schools, and the federal government. Of over 4,000 people examined in five counties, 12.5 per cent. had this disease. A report from the W. C. T. U. Settlement School at Hindman, by Miss Lucy Furman, author of "Mothering on Perilous," names twenty-five per cent. for that locality. Adenoid and turbinate cases are common. President Murdock says that several clinics held at his Presbyterian college at Buckhorn revealed that ninety per cent. of those examined were afflicted with hookworm. Splendid work is being done, but the area to be covered is a vast one, and assistance is needed greatly. Superstitions that diseases are visitations of the Lord to be borne with resignation are disappearing slowly.

The people continue to be poor. In 1900 land was worth $5.00 per acre, and 1910, $9.66 (Kentucky, $13.24 and $21.83; Indiana, $31.76 and $62.36). The average value of all farm property per farm in 1900 was $860; and in 1910 it was $1,359 (Kentucky, $2,007 and $2,986; Indiana, $4,410 and $8,396). The average value of farm buildings per farm in 1910 was $247 (Indiana, $1,230).

Institutions

There is great need of education. In 1900, 24.3 per cent. of the voters were illiterate, and a decade later, 20.7 per cent. (Kentucky, 15.3 and 13; Indiana, 5.6 and 4.1). In eight counties, in 1900, the illiterate voters constituted from 30.5 per cent. to 35.8 per cent. of the total. In 1910, 61.6 per cent. of the children, ages six years to twenty, were in school (Kentucky, 60.8; Indiana, 66). Corresponding figures for children from six years to fourteen years were 73 (Kentucky, 76).

However, improvement is being made. In 1900, there were more than 20 counties without a local publication. Now, there are but few counties without a press, and several have more than one.

Formerly, the term of school lasted but three months in the year. The teachers received no training except in the common schools. The buildings were tiny, two or three teachers in some cases teaching in the same room. But now, the term lasts six months (closing at Christmas owing to bad roads). Also, many of the teachers receive some training in the normal department of the settlement and missionary schools. Furthermore, there is but one teacher in each room, though in it are no library, few modern desks, and little equipment. In one mountain school visited by the writer in 1914, the pupils were sitting in rough board pews, the boys on one side of the room and the girls on the other.

The walls, floors and seats were dirty. Two of the children were suffering from trachoma. The equipment owned by the school consisted of one wall map and three calendars. The only object on the desk was a small switch. The girl-teacher, who was a graduate of the institute at Oneida, had charge of 69 pupils and, besides, was teaching, without pay, a "moonlight" school of evenings, to which people of all ages were coming. She did not show any surprise or nervousness when our group of ten men in nailed boots filed in. Nor did the children pay much attention to the visitors. The third grade droned out its reading lesson, and then the second grade carried out its solemn program in spelling. There was a solemnity about it all which the outsider does not understand until he becomes acquainted with the gravity of these people in their gatherings. Progress was being made, though it seemed a pity that the children should have to learn the definition of some words which probably they never will have occasion to use. The day of the "shouting school" (in which the pupils indicate that they are studying by reading aloud) has passed in the mountains. In a second school, a girl, younger than the first teacher, was in charge. She had had no training beyond the common school. There were a few modern desks, but also some rough hewn pews. When I tiptoed to the door and took a photograph of the interior she showed less surprise than an Indiana schoolmistress would have exhibited, but she smiled when some of her children awakened to the situation. In a third school a middle-aged man was in charge. He said that in some sections a holiday week is declared during the corn-harvesting season. We visited also the mission and W. C. T. U. settlement schools, which are coming into the country; as at Buckhorn, Hindman, Pine Mountain Postoffice, and Blackie. In these schools, conditions are much better. Many of the teachers are college graduates. I have in mind one of them, a young woman, who would be considered an excellent teacher in any of our universities. One of the teachers had just returned from a vacation in New England, and another, from Paris. It was a privilege to meet these people of genuine culture among the hills. Their helpful and unselfish presence among the mountaineers is a good omen. An unfortunate feature of these institutions is the extreme scarcity of men teachers.

Berea College, on the western margin of the region, serves as a university for the mountains, and is sending its extension department with wagon and camp into the remote sections. The reader is referred to the December, 1912, number of *The American Magazine,* for the story of the heroic foundation of Oneida Baptist Institute, and is reminded of Bulletin Number 530 of the United States Bureau of Education, for the story of the opening of "moonlight" schools in the Kentucky mountains in 1911 for children, parents and grandparents. When the feud breaks out, mountain mothers from the section in which blood is shed,

FIG. 13. MANUFACTURING IN THE HEART OF THE HILLS, NEAR PINE MOUNTAIN POSTOFFICE.

anxious to get their sons out of danger, are wont to urge them to attend school at Berea College and elsewhere.

Though in some sections enthusiasm for education is becoming great, in others there is great apathy, because of lack of interest on the part of the people, lack of practical teaching, illiterate teachers, poverty, poor roads and political interference in school affairs. In some districts it is still thought by the school trustee that "the lickenest teacher makes the knowinest younguns." Changing conditions are indicated by an incident in which two teachers appeared in the same school room, each determined to become the sole teacher. The following among the pupils was about equally divided at first, but presently they moved away from the teacher using the "A, B, C" method and grouped themselves about the more progressive instructor who was following the sentence method. The broad effect is being made to teach the people how to work and live according to modern ideas, and yet to retain the desirable traits of their own civilization. This is a delicate task, involving much more than merely academic training.

Religion is undergoing transition slowly. Formerly if a speaker did not shout and gesticulate he might be termed a good *speaker* but not a good *preacher*. The early attitude towards the settlement workers was indicated in a mountain sermon in which the congregation was told to "beware of the fetched on women who come in here wearing gold watches, and their shirt fronts starched so slick that a fly would slip off and bust out his brains." But, a year later, the mountaineer said that since these women were administering to the needy under conditions so harsh that even the mountain people would not venture out, "I allow as how they are welcome to stay in the mountains as long as I live." One mountain patriarch, who has given his farm and essentially his all in

founding a settlement school in the valley of his home, gave some of his reasons for doing so essentially as follows: That there was much whiskey and wickedness in the community where his grandchildren must be reared "was a serious thing for him to study about." Also, he heard two of his neighbors say that there is neither heaven nor hell. Furthermore, one of them told him that when a man is dead he is just the same as a dumb beast. And another said that he could not rear his large family of children to be as mean as he wished. With these conditions in mind the founder hoped that by starting a good school he "would help moralize the country." Formerly the Presbyterian religion was most prevalent, but it gave way to the "Hard-shell" Baptist creed, since in the mountains the educational qualifications for the latter were less severe than for the former. The disciples of this religion have in turn given way before the "Missionary Baptists." Methodists are also numerous. The most vivid disputes in the mountains were wont to be about religion. But now there is a significant change toward toleration in that preachers frequently exchange pulpits with pastors of other denominations, and that the use of a church is often tendered to another denomination which temporarily is without a place of worship. The following can be interpreted as a groan of growth. "The church in eour holler, hits about dade. Part ov the folks want an eddicated preacher, and parts wants an old timer, an so they don't get nary one." The funeral preaching had become the sole opportunity for social gathering until the recent advent of "camp meeting week," and the coming of the extension school on wheels.

Changing conditions have not yet affected greatly the political situation in the mountains. Since the Civil War so many of the inhabitants have been Republicans that party arguments have been one-sided, and the contests have been within the organization. Unity of feeling in the

FIG. 14. THE ROAD FROM LINE FORK TO THE HEADWATERS OF GREASY CREEK. This is one trade route of the 500 people living near that creek.

FIG. 15. A MOUNTAIN SCHOOL. The girl-teacher also "holds" "moonlight school" in this building.

mountains gives the representatives considerable power in the State Legislature. Political discussions are said to be confined in general to stump speeches concerned with national issues, and hence are of little help concerning local problems. However, since the mountain men are good at politics, some make a profitable business of the local contests. Recently in some sections some are said to have turned their attention to the school, for the sake of profit in the appointment of teachers. There the trustee runs for office upon a platform-statement of which teachers he favors. In some sections the vote runs high in school elections, while it is light on other matters. An increasing number of women vote on school affairs. Another favorite field of the politician is the handling of road taxes.

Deep-seated prejudice, due to poverty, exists against taxation of any kind. In 1906 the per capita state-and-county tax was $4.62 for Woodward County, in the Blue Grass, while in the mountains it ranged from $.40 in Elliott County to $1.75 in Harlan. Little returns are obtained by taxation of lumber and mineral resources.

The feud was transplanted from Europe into the Blue Grass, the Kentucky Mountains, and elsewhere. It survived among the isolated valley of the mountains, where it was fostered by folk-song, the flaring resentment of the Indian fighter and pioneer, and the habits of thought natural in isolated communities where for a long time there was neither sheriff nor jury, and where, even to this day, the government hardly has been able to inspire confidence or dread. The Civil War greatly increased and intensified the feud: Prior to 1860, few weapons had been used in the mountains, and few deaths had resulted. In the region in 1860 there were 10,098 slaves and 1,280 free colored people. The lines grew sharp between the Union and Confederate counties, as well as

between opposing families, and between opposing members of a family. Modern arms were introduced into the region. The physiography of the land favored bushwacking. During the war the Kentucky mountaineers suffered more sharply than the mountain people of any other state, except Tennessee. Also, many of the principals of the post-war feuds were boys during the Civil War, whose imaginations were filled with the horrors which the mountains witnessed during the four years. It is said by the mountain people that the actual numbers engaged in the feuds has ranged from 10 to 60 on a side; that the duration has been from 1 to 40 years; that perhaps not 10 per cent. of the mountain people have had a personal difficulty sufficient to cause fighting; probably not 40 per cent. of them have gone to a court house to prosecute or defend a case; and that half of the enlisted partisans never have faced the music on a showdown fight.

In some parts of the region, as about Oneida, education is causing the decline of the feud; but in other sections it flourishes, as near Pound Gap ("Trail of the Lonesome Pine"), near where, it is said, some eleven men were killed in three months during the spring of 1914.

The home, also, is changing. One still can see the windowless log cabin with its "dog-trot"—the open passage way between the two rooms; but some roofs are of shingles, and some of tin, while frame structures are appearing, and brick. Mountain simplicity and hospitality are illustrated by one man who said, "I want a good house; two rooms . . . one for the family and one for company, each big enough for a bed in every corner . . . and a lean-to cook room."

The following is a description from Professor Penniman's unpublished tales of the mountains:

Three days are ample to build a log-cabin twenty feet square. The part before the roof is called a "pole pen." This is run up in a few hours. The

FIG. 16. THE PRESBYTERIAN MISSION SCHOOL AT BUCKHORN.

FIG. 17. THE ONEIDA BAPTIST INSTITUTE, founded by John Burns, of the moun-

trees sufficient to build a cabin complete are often standing on an acre. With the roof up, and stone chimney on the outside, and the big fireplace opening into the room, the young people can begin housekeeping. A few saplings will make a bed frame fastened to the logs in one corner, and a bed without a tick, two feet thick, of fresh pine needles, gives a sense of luxury to the newly married pair.

Customs and Habits

It must be remembered that there are all grades of society in the mountains, and that no general description can be applied to a specific case.

Woman is inferior to man in both number and position. In 1910 the males numbered 289,315, and the females, 272,566. Not only is she a household drudge, but a field hand as well. (Out-of-door work in itself, of course, does not constitute drudgery.) She still follows behind him as they trudge over the mountain. A mountain boy, upon being asked how many brothers he had, answered me promptly: "Two." But concerning the number of sisters, he drawled: "Oh, three or four." The modern Woman Movement hardly has penetrated into the hills, and, when it does, it will meet orthodox opposition. However, women increasingly vote in school affairs in some districts. Furthermore, here and there, a girl returns from Berea, or some other college, with ideas strange to her people. Perhaps this explains the wide girdle, or other bit of modern adornment, now seen sometimes on the quaint costumes.

We were pushing through a deep forest in climbing over a ridge.

tains. This was the scene of the Baker-Howard feud. (Photo by H. Hesse.)

Before us were two children, walking in single file, a boy of fourteen and a girl a year younger. Our youthful guide pointed in their direction and remarked; "They were married last spring. Some of us do get married that early hereabouts; but we who have been to the settlement school don't calculate to get married that soon."

"Store clothes" have displaced homespun garments, the result being unfavorable in the appearance of the men. However, the settlement schools are reviving the home-weaving industry to some extent. The belt is beginning to rival the suspender on "Sunday" garments.

The quaint Old English language also is disappearing, though slowly. It is becoming crystallized and is losing its flexibility whereby it was wont to be bent this way or that, to suit the fancy or fit the occasion. In a reminiscence of his boyhood, Professor Dizney tells of a minister in Dizney's valley, who, in preaching about apostasy, took as his text: "If they shall fall away," and who concluded in a high key:

> "If they shall fall away," means that they can not fall away, for anybody who knows anything about the English language knows that it is a verb *in the impossible mood and everlasting tense!*

There also comes to mind the following expression: "Law me, Honey, I'm glad to be back from the plains. Wooded mountains make the restinest place to lay your eyes on."

There is about to pass away a most interesting folksong based upon English and Scotch ballads, and preserved verbally in the mountains with slight modification, from generation to generation. These songs

of romantic love, hate, sacrifice and revenge are sung in almost all of the log cabins. Thereby the visitor, who may have thought that the mountaineers neither weep nor smile, learns with delight that their natures are intensely fluid. The songs are sung in slow time, and in minor tones difficult to express in written music. An effort is being made to collect the words and write the music before it becomes too late.

The open hospitality, once common, is shrinking. An old man in his watermelon patch put it thus: "I used to raise melons for the whole valley, so that the folks would come to sit and talk with me on the porch while we ate them. But now too many foreigners have come in; they would eat me out of home." There is a kindly affectionate courtesy for one another among the people, which, it is hoped, will survive.

There is such a great need for improvement in sanitation that what has taken place is negligible.

The native is accustomed to work in his fields by seasons, with periods of rest between. In fifteen days of travel I saw, during one of these "off" periods in September, but two men at work in the field. It has been his wont to work during the favorable time, or when the larder is empty; or to rest during the unfavorable season, or while provisions are at hand. Therefore, in general, the population is unsuited to the routine of work in the mines, the manufacturing plants, and the lumbering camps, now appearing in the region under the control of outside capital. Furthermore, it is without a disposition to cooperate. Hence such workers are at once the despair and menace of the employer and the labor union. Consequently, foreign labor is imported, and the mountain man is in the way, as was the Indian. He will not necessarily become happy if, to meet modern industrial conditions, he throws off lightly his old attitude toward life gained through centuries of adaptation in the mountains. A few of the most versatile natives are profiting by the rapid changes; but the great majority, formerly independent land-owning farmers, are not. Many are seeking employment in mill or mine, or are withdrawing to the headwaters. It is significant that the leaders in the mountains, native and mission, deplore the *rapid* advance of industry into the region, and that they are bending every effort to prepare a civilization over a century in arrears, to meet the rude shock of the worst of our culture. In the 1911 term of court, Perry County, being invaded rapidly by railway construction, had nearly 600 cases: Owsley County, without access to railways, had less than 40 cases. A mountain guide in Pound Gap lamented, "The devil is coming into the mountains on wheels." Eight years ago I rejoiced with a clean cut, delightful, energetic man who was returning home from the Kentucky Mountains buoyant because he had doubled his fortune by securing some of the virgin forest at an absurdly low price. He was bringing wealth and good cheer to his northern family. Now, with those slopes in mind. deforested, gullied, scorched, and sold ("unloaded"), I am not rejoic-

ing. Most of the mineral rights have been bought by outside capital, much for \$1.50 per acre, and in some cases for \$.50. Sometimes the mountain people made the further mistake of giving up the farming rights also. At Jenkins the wives were paying high prices at the company stores. Twenty miles from one of the new mining towns, a mountain girl, grown coarse by contact with the frontier of civilization, boarded our train and by her lewdness shocked, among others, two refined young women of the hills to such an extent that one of them said: "I am ashamed that I am a woman," and was answered by her comrade: "I'll hush forever on the train." The *rapid exploitation* of the natural resources of a region by outside capital tends to harm the native, especially if his civilization is not modern. In this case the outcome is in the balance.

The Future

If exploitation pure and simple continues, twenty-five years will bid fair to bring about the following results: The disappearance of this race of true Americans as a unit; the passing of the valuable timber; numerous forest fires in the region slashed over; greatly increased erosion of the steep hillsides with their soil already thin; short periods of flood within and below the region; long intervals of low water within and below the region; the reduction of fish and game; the introduction of a foreign mining element, also a foreign manufacturing body; and a district of great natural beauty changed to a region of squalidness. Presently, with the increase of population and the value of land in the United States, the wastes may be reclaimed at great cost.

Outside aid might do the following things: Regulate the exploitation of the coal and timber so that it will be gradual; aid the counties in building good roads; assist in educating the mountain people along broad lines to close the gap between them and us; help them to develop stock-raising, fruit-growing, scientific agriculture and scientific forestry. Some of the results would be: The saving of the mountain race as a unit; the addition of a happy, prosperous, food-supplying area to the United States; the prevention of the disasters of soil erosion and of flood; and the utilization of water power.

There is one thing more which might be done. It is being pointed out that men break down under the tension of modern industrialism, unless they, somewhow, are brought into contact with the beautiful, and get away for frequent moments of change and recreation. The government owns our national parks; but they are far out west, beyond the financial reach of the average worker. The government might also establish numerous small parks in the Southern Appalachian Highlands, which would become the recreation ground of millions of workers east of the Mississippi River.

Ronald Ross

RONALD ROSS AND THE PREVENTION OF MALARIAL FEVER

By MAJOR GENERAL WILLIAM C. GORGAS
SURGEON GENERAL, U. S. ARMY
AND
FIELDING H. GARRISON, M.D.
WASHINGTON, D. C.

On Wednesday, December 10, 1902, at Stockholm, the Nobel prize for medicine, the second to be awarded, was bestowed upon Sir Ronald Ross for his demonstration of the transmission of malarial fever by mosquitoes. His immediate predecessor in the medical award was von Behring (1901), his successors were Finsen (1903), Pavloff (1904), Koch (1905), Golgi and Ramon y Cajal (1906), Laveran (1907), Metchnikoff and Ehrlich (1908), Kocher (1909), Kossel (1910), Gullstrand (1911), Carrel (1912), Charles Richet (1913), and Robert Bárány (1914). In this distinguished company it is noticeable that no less than three of the prizemen—Ross, Golgi, Laveran—were honored for their scientific work on the causation of malarial fever. To understand the significance of Ronald Ross's career, let us briefly consider the history of this disease.

Malarial fever has been known from the earliest times. It is well described in the medical writings of the ancient Greeks and Hindus. The intermittent forms, commonly known as quotidian, tertian and quartan, had already been differentiated by Hippocrates, who noted the principal symptoms, established a connection between the characteristic malarial enlargement of the spleen and marshy stagnant pools of water, and attributed the disease to the drinking of such water. Before the fifth century B.C., Greece was a mosquito-ridden country, but free from malaria. The disease was probably introduced by immigrants, as happened at Mauritius in 1866. After the age of Pericles, references to it became more extensive in literature, and the resulting rural depopulation had much to do with the downfall of Greece. The physicians of modern Greece have found the swamp fevers of their country to be not different from those described by Hippocrates in Thessaly and Thrace. One of them, Cardamatis, holds that some of the labors of Hercules symbolize the reclaiming of marshy areas from malarial fever, which he thinks identical with the "epiala" of the poets Theognis and Homer. The philosopher Empedocles (fifth century B.C.) was actually deified by the townsmen of Selinus for freeing the Sicilian city from malarial fever by draining the swamps in its vicinity. The Romans had a special goddess of fever (Mephitis), a bald, emaciated, dropsical figure who had a temple

on the Capitol, and whose very name suggests the swamps and their exhalations. The summer and autumn dangers of the Campagna were well known to the Roman satirists, Horace and Juvenal, who also mention the mosquito-net (*conopeum*). The close attention which the Roman architects paid to the construction of splendid aqueducts and drains shows their intuitive feeling about these things. A number of Roman writers on agriculture and architecture attributed malarial diseases to swamps, to the emanations from them, and to the small living creatures found in them. As these citations, first given by Lancisi, are always quoted in the original Latin, it may be well to translate them.

Varro (116–27 B.C.), writing on husbandry, says:

> It should be noticed whether any localities are marshy, for the same reasons, and because, when they dry up, certain minute animals are engendered, which the eyes can not see and which get into the body through the air by way of the mouth and nose, causing troublesome diseases.

Vitruvius, the architect (first century B.C.), says:

> The vicinity of a marsh is to be avoided, because, when the morning airs reach the house at sunrise, the mists of these places arrive with them, and the wind, mixed with these vapors, spreads the poisonous exhalations of the creatures inhabiting the marsh, and so makes the place pestilential.

Columella, the agriculturist (first century A.D.), says:

> Nor should buildings be erected near a marsh nor a military road adjoin it, because through heat it gives forth noxious poisons and engenders animals armed with dangerous stings, which fly at us in dense swarms.

Palladius says, in his poem on agriculture (fourth century A.D.):

> A marsh is by all means to be avoided, especially one lying to the east or west, and usually drying up in summer, because it engenders pestilence and harmful animals.

These extracts show that from the second century B.C. to the fourth century A.D. and after, the Romans had a clear notion of the relation between the fauna of marshes and malarial fever. The Hindus went even further. In the Susruta, a Sanskrit medical treatise which is at least 1,400 years old, the symptoms of malarial fever are clearly described and attributed to the bites of certain insects. Hints as to the connection between marshes and malarial fever will be found scattered through secular literature everywhere, for instance, in the dismal illustrations of the first edition of Mrs. Trollope's "Domestic Manners of the Americans," representing the ague-ridden inhabitants of the banks of the Mississippi, or in such a tale of the marshes as Baring-Gould's "Mehalah." Dr. Holmes, in "The Autocrat," likened the intermittent forms of malarial fever to certain short-lived insects—in that they "skip a day or two."

In 1618, the Countess Chinchon, wife of the viceroy of Peru, was healed of an intermittent fever by the use of cinchona bark, which was

introduced into Spain by her physician, Juan del Vigo, in 1640. The fact that cinchona, being a specific, not only cures malarial fever, but also differentiates it from other infections, gave a peculiar impetus to the study of the disease, which was carefully followed in England by Sydenham and Morton, in the seventeenth century, by Lind and Pringle, in the eighteenth century, and in Italy, by two great physicians, Lancisi and Torti. Lancisi, in 1717, published a large treatise on the noxious airs of swamps,[1] in which he revives views of the earlier Roman writers about the insects arising from them, in particular, the mosquitoes (*Culices*), of which he gives a naturalist's account, even suggesting their possible agency in inoculating disease. While he still held, in part, to the ancient doctrine of miasms or effluvia taken into the body *via* the respiratory and alimentary tracts, he was prone to regard these effluvia as organized or organic. The following luminous sentences, which have not been translated before, reveal the quality of his vision:

Cap. XVII., III. (p. 61): In a previous chapter, I have shown that mosquitoes (*Culices*) and other insects make their nests on the water during summer. It can therefore be easily seen that near swamps, where there are so many kinds of organisms and whence their multitudes are thrown into the surrounding air, the water, which the inhabitants use for drinking, is infected with these organisms.

Cap. XVIII., IX. (p. 66): Furthermore, no controversy can surely arise among professional men concerning the harmful effect which the insects of the swamps inflict upon us by mixing their noxious juices with their saliva and gastro-intestinal fluids. For, as I have shown above at length, their proboscis is always wet, and, as all their viscera are full of deleterious liquids, it is not possible that the juices rolling down with food and liquids into the stomach, are not there mixed with our ferments. . . . For this reason, we may conclude that marshy insects are highly injurious to the body of man by the inmixture of deadly juices as well as by the withdrawal of the useful ones which are in us.

Cap. XIX., III. (p. 72): Moreover, I take the rôle of a seer and not of a philosopher if I, without experiments, venture to affirm that, in camp fevers of this sort, the worms penetrate and ascend the blood vessels. For it would be necessary that the blood of those suffering from marsh fevers should be let, which medical reason seldom admits; and to carefully examine the blood with a microscope for insects of this kind, if such there be. But, although worms might be seen in the drawn blood, it would still be doubtful that these insects should be considered as the cause of the evil; or whether, which I consider more probable, it is the product of the breaking down of the fluids; whence all the minute ovules, after they have been wrapped up in particles of the blood, are set free or are supplied from the external air. I can therefore form no opinion from autopsies whether these diseases are carried by insects into the blood. Being rather content with a confession of my own ignorance, I must frankly concede that neither in abscesses due to nature or produced artificially in patients who frequently come from the neighboring swamps to Rome, nor in the examination of dead bodies, have I found insects in other viscera than the stomach and intestines, where they found room, quietude and food more easily than

[1] G. M. Lancisi, "De noxiis paludum effluviis eorumque remediis," Rome, 1717.

elsewhere. For the rest, through the supreme goodness of God, I have never been called upon to treat the plague, and, for this reason, I gladly refrain from expressing a definite opinion concerning pestiferous worms in the blood, as being a thing I know almost nothing about.

Lancisi also shows that good drainage drives away fevers. The great aqueducts and drains of the ancient Romans had apparently been designed for this purpose, and, through the Middle Ages up to the nineteenth century, the Papacy made many efforts to drain the Pontine Marshes and to cultivate the deserted Campagna, methods of sanitation which Ross summarizes as the "principle of mosquito reduction." Torti, at Modena, introduced cinchona bark into Italian practise, and by its use differentiated the pernicious forms, which do not yield to treatment, and of which he gave the classical account (1712). He also introduced the term "malaria," from the Italian *mal'aria* (bad air). The expressive term, first employed in English by John Macculloch, in his treatise "Malaria" (1827), epitomizes the earlier theory of its causation, viz., that it is due to miasms or effluvia, *i. e.,* gaseous emanations given off by stagnant water or even by the earth itself.

The next step in the history of malarial fever was the discovery of the parasites causing the disease. The theory that diseases may be caused by minute living organisms, invisible to the naked eye, is also very old, as is plain from the above citation from Varro. It was first stated in scientific form by Fracastorius, in his treatise on contagion (1546), and later by Athanasius Kircher (1658), who investigated minute organisms with the microscope. In 1730, as cited by Professor W. S. Thayer, Thomas Fuller, an English physician of the eighteenth century, made the following quaint suggestion that malarial fever may be caused by minute organisms:

Can any Man, can all the Men in the World, tho' assisted by Anatomy, Chymistry, and the best Glasses, pretend positively and certainly to tell us, what particles, how sized, figured, situated, mixed, moved, and how many of them are requisite to produce a quartan ague, and how they specifically differ from those of a tertian?

Agostino Bassi, who discovered the microorganisms causing silkworm disease, relates that the physician Rasori of Milan said to him of his discovery:

I am fully persuaded of the truth of your useful discovery. For many years I have held the opinion that the intermittent fevers are produced by parasites which call forth a new paroxysm by the act of their reproduction, which occurs at more or less rapid intervals according to the diverse species. In this way, the intermittent fevers, quotidian, tertian, quartan, arise (1846).

In the meantime, Jacob Henle had published his essay "On Miasms and Contagia" (1840), stating his theory of living contagia, with reference to Bassi's work; and, in 1849, Dr. John K. Mitchell published his treatise "On the Cryptogamous Origin of Malarious and Epidemic

Fevers," in which these diseases are attributed to minute fungi. This essay is a landmark in the history of the doctrine of contagion, but, for our purpose, the most important sentences in it are the following, referring to the causation of malarial fevers:

> Whatever may be their cause, it seems to have activity almost solely at night. *Darkness* appears to be essential to either its existence or its power.

Yet, strange to say, Mitchell, carried away by his theory of a fungous cause, says nothing whatever about mosquitoes, which were coming to be recognized more and more as agents in the production of both malarial and yellow fevers. In an old ordinance of Freetown, Sierra Leone, dated 1812, and cited by Kennan, the inhabitants (mostly freed slaves) are enjoined to keep the road in front of their plots in good condition in order to prevent the formation of "stagnant pools which generate disease and mosquitoes over the town" (Ross). In 1848, Dr. Josiah C. Nott, of Mobile, Alabama, advanced the provisional theory that yellow fever and malarial fever are of "probable insect or animalcular origin." It is sometimes asserted that Nott regarded the mosquito causation of malarial fever as proven. The only statement in his brilliant but rambling essay which suggests anything of the kind is the title of the paper itself, viz., "Yellow Fever contrasted with Bilious Fever—Reasons for believing it a disease sui generis. Its mode of Propagation—Remote Cause—Probable insect or animalcular origin, etc."[2]

The explanation of Nott's statement is simple. He got his theory of malaria, as every one else did, from Lancisi. In 1854, Louis Daniel Beauperthuy, a French physician residing in Venezuela, assigned a definite species of mosquito as the cause of yellow fever, holding that the poison is injected under the skin by the insect, as in snake bite. In 1866, Salisbury attributed the causation of malarial fever to spores of the vegetable family Palmella, and in 1879, Edwin Klebs and Tommasi-Crudeli announced the discovery of a *Bacillus malariæ,* neither of which availed as the true cause. The next few years witnessed a sudden leap in knowledge. On November 6, 1880, Alphonse Laveran, a French army surgeon, working at Constantine, Algeria, discovered the parasite of malarial fever, and in 1881, described three of its forms. In 1881 also, Dr. Carlos J. Finlay, after making a series of careful bionomic observations and some inoculation experiments, announced that yellow fever is transmitted *from man to man* by a special species of mosquito (*Stegomyia*[3] *calopus*), a theory which was to be proven in the most rigorous way by Major Walter Reed, of the U. S. Army Commission, and

[2] J. C. Nott, *New Orleans Med. and Surg. Jour.,* 1847–8, IV., 563–601. See on this point the essay of Dr. Juan Guiteras, "Insect-borne Diseases in Pan-America," Habana, 1915, p. 33.

[3] Finlay, *An. r. Acad. de cien. med. . . . de la Habana,* 1881–2, XVII., 147–169.

his associates, Carroll, Lazear and Agramonte, in 1900. Prior to Finlay however, Sir Patrick Manson had, in 1879, demonstrated that the mosquito transmits the disease produced by the parasite *Filaria*. In 1883, Dr. A. F. A. King, an English physician residing in Washington, D. C., gave nineteen cogent reasons why mosquitoes should transmit malarial fever and suggested screening the city from the marshy Potomac flats. In 1884, Carl Gerhardt demonstrated that malarial fever can be transmitted from the sick to the healthy by inoculation of the blood of the former,[4] in other words, as Ross says, "that the disease is not due to any gaseous emanation from the marshes, but is a true infection by some living virus." This laboratory demonstration of Gerhardt's may be said to have abolished the Miasm Theory of malarial fever. In 1885–6, Camillo Golgi,[5] at Pavia, showed that the Laveran parasites reproduce by formation of spores, and that the paroxysm of fever begins, as Rasori had surmised, just when the spores are liberated. That the parasites of the different forms of intermittent fever are different from each other and that similar parasites are found in birds was speedily shown by Marchiafava, Celli, Grassi and other Italian observers. In 1884, Laveran, and, about the same time, Koch, suggested that mosquitoes, as abounding in marshy places, may play the same part in malarial fever which Manson had shown them to play in filariasis. In 1894, Manson, in drawing a parallel between the malarial organism and *Filaria nocturna,* suggested that "the mosquito having been shown to be the agent by which the *Filaria* is removed from the human blood vessels, this, or a similar suctorial insect must be the agent which removes from the human blood vessels those forms of the malaria organism which are destined to continue the existence of this organism outside the body. It must, therefore, be in this or in a similar suctorial insect or insects that the first stages of the extra-corporeal life of a malarial organism are passed."[6] It is just at this point that the work of Ronald Ross looms large in importance.

Lieut.-Col. Sir Ronald Ross, K.C.B., F.R.S., the son of General Sir C. C. G. Ross, an eminent English soldier, was born on May 13, 1857, received his medical education at St. Bartholomew's Hospital, London, graduated in 1879, and entered the Indian Medical Service in 1881. He began to study malarial fevers in India in 1889. Doubting the truth of Laveran's discovery, he at first, after the fashion of Broussais, regarded the infection as the result of intestinal auto-intoxication. Being in London in 1894, he became acquainted with Manson's mosquito theory and upon returning to India the next year, undertook to verify

4 C. Gerhardt, "Ueber Intermittensimpfungen," *Ztschr. f. klin. Med.*, Berl., 1883–4, VII., 372–377.

5 C. Golgi, "Sull' infezione malarica," *Arch. per le sc. med.*, Torino, 1886, X., 109–135.

6 Manson, *Brit. Med. Jour.*, Lond., 1894, II., 1306.

it by experimental demonstrations. In 1895, he received the triennial Parkes Memorial Prize of 75 guineas and a gold medal for the best essay on "Malarial Fevers: their Cause and Prevention," Manson and Sir Almworth Wright being among the judges of the eleven essays presented. This essay simply summed up what he had learned from Manson.

Lancisi and his successors held that the malarial parasite or poison may somehow be carried from the marshes to man by mosquitoes. Manson, applying the analogy of his theory of the transmission of filariasis by the mosquito, thought that the insect carries the parasite from man to the marshes, laying her eggs on the surface of the water and dying in the act of doing so. He inferred that the embryos of the malarial parasite infect man by the digestive tract through the drinking of contaminated water. But long before Manson had taken up this hypothesis, it had been completely disproved by the Italians, Marchiafava (1885), Marino (1890) and Zeri (1890), whose careful experiments showed that it is impossible to infect healthy persons by the ingestion of water from the marshes. When Laveran investigated the malarial parasite in 1880, he found that certain large cells in the withdrawn blood give off long motile filaments, like the tentacles of the squid, which were supposed by Grassi, Bignami and other Italians to be the effect of the death agony of the parasite *in vitro*. Manson inferred that these filaments are in reality flagellate spores which escape from the parent parasites taken from the patient's blood by the mosquito and develop into the matured forms afterwards found in other malarial blood. So far, his theory explained how the parasites escape from the blood of an infected patient into the external world *via* the mosquito. But the important question was, how do they get into the body of a healthy patient and infect him with malarial fever? Ross soon found, like the Italians before him, that the hypothesis of the infection of the alimentary tract by drinking water falls to the ground completely. The real point of attack was obviously the motile filaments. He began his work at the malaria-ridden post of Secunderabad in 1895. In prosecuting his researches, he had first to devise methods for collecting, classifying, feeding, breeding and dissecting the mosquitoes themselves. He soon found that his Indian insects fall into three general classes, the brindled mosquitoes (*Stegomyia*), the gray (*Culex*) and the dappled or spotted-winged (*Anopheles*). He caused mosquitoes hatched from larvæ of these varieties to bite malarial patients and tried to find the parasites in the bodies of these insects, which were obviously free from malarial or other extraneous parasites of any kind. For two years, with constant improvement of technique, he labored at this problem without much success, his work being interrupted by a year and a half's detail to fight a cholera epidemic at Bangalore and by the Afridi War. At Bangalore, he made some inoculation experiments with mosquitoes upon Mr. Appia, assistant surgeon of the Bowring Civil

Hospital, and others, but without success. His natural inference was that either the disease is not inoculated by mosquito bites or that he had not got hold of the right kind of mosquito for the purpose. In April, 1896, he was sent to Ootacamund, a great hill station in the Nilgiri Hills, 8,000 feet above the sea level, and here among the tea and coffee plantations at the foot of the malarial Sigur Ghat, a trench-like hollow in the hills, he made his first step in advance, for here he found and began to concentrate his attention upon the dapple-winged *Anopheles* mosquito, which was to prove the true vector of the disease. Ordered back to Secunderabad in July, 1897, he repeated all his experiments upon the gray and brindled mosquitoes, without success, but did not get hold of any specimens of *Anopheles* until August 15. In the stomach of one of these, he found, on August 20, a delicate circular cell containing minute granules of a black substance like the melanin pigment, discovered by Meckel in 1847, which was shown by Virchow and Frerichs to be the essential pathological product of malarial fever, and is found in the malarial parasite. The next morning, he found in his eighth and last *Anopheles* similar bodies, only much larger.

> Both insects had been bred from larvæ in captivity; both had been fed for the first time on the same person—a case of malaria; no such objects as these pigmented cells—as I then called them—had ever before been seen in the hundreds of mosquitoes examined by me; the objects lay, not in the stomach cavity of the insect, but in the thickness of the stomach wall; all contained a number of black granules precisely similar in appearance to those contained by the parasites of malaria, and quite unlike anything which I had ever seen in any mosquito previously. Lastly these two mosquitoes were the first of the kind which I had ever tested. . . . These two observations solved the malaria problem. They did not complete the story, certainly; but they furnished the clue. At a stroke they gave both of the two unknown quantities—the kind of mosquito implicated and the position and appearance of the parasites within it. The great difficulty was really overcome; and all the multitude of important results which have since been obtained were obtained solely by the easy task of following this clue—a work for children.[7]

Shortly after confirming these results, Ross received peremptory orders to proceed to Kherwara in Rajputana, a petty non-malarial station, 1,000 miles distant, which he describes as "my Elba—almost my Île du Diable," for here his researches were interrupted until February, 1898, when he was given a six-months detail to investigate malaria and kala azar in Calcutta and Assam. In the meantime, W. G. MacCallum, at the Johns Hopkins Hospital, had discovered that the motile filaments of *Halteridium,* a parasite in birds, are agents in sexual conjugation, and in 1898, MacCallum and Eugene L. Opie demonstrated the same thing for the malarial parasite. Working with *Halteridium* and *Proteosoma,* both malarious parasites of birds, Ross proved at Calcutta on March 20, that *Proteosoma* can be transmitted from bird to bird by

[7] Ross, *Jour. Roy. Army Med. Corps,* Lond., 1905, IV., 551.

the gray mosquitoes (*Culex fatigans*), which, as he says, "practically proved the mosquito theory of malaria." He confirmed his results by a long series of differential experiments, which he transmitted to Laveran and Manson in letters of April 22, 1898, and after some interruptions, he discovered at Calcutta, on July 8, 1898, that the spores of the parasites were concentrated, not in the intestine, as he and Manson had supposed, but in what proved to be the *salivary gland* of the mosquito.

> The exact route of infection of this great disease, which annually slays its millions of human beings and keeps whole continents in darkness, was revealed. These minute spores enter the salivary gland of the mosquito, and pass with its poisonous saliva directly into the blood of men. Never in our dreams had we imagined so wonderful a tale as this.[8]

In confirmation of this, he infected a large number of sparrows with *Proteosoma* from gorged mosquitoes and his results were communicated by Manson to the British Medical Association in July, 1898. They attracted wide attention among the scientific experts but were absolutely ignored by the governmental and military authorities. Colonel Ross, his financial resources exhausted by these investigations, determined upon leaving India and returned to England in February, 1899. Shortly afterward, he was appointed first lecturer on tropical medicine at the newly created Liverpool School of Tropical Medicine, and here a new phase of his life work began.

In this year (1899), the Italians B. Grassi and A. Bignami gave conclusive evidence that the malarial parasites develop only in the *Anopheles* mosquito[9] and the causal relation was now definitely established. The next step lay in the direction of preventing the disease.

In August, 1899, Ross was sent out by the Liverpool school to investigate the West African coast fevers at Sierra Leone. Landing there on August 10, he soon found that two species of dapple-winged *Anopheles* (*A. costalis* and *A. funestus*) are the agents of transmission, and he immediately proceeded to establish for the first time the fundamental principles of the prevention of tropical malaria, viz., the culicidal treatment of the stagnant pools which were found to be the breeding places of *Anopheles*, scrupulous drainage of the soil, screening of buildings with wire gauze, isolation of the sick, and the habitual employment of mosquito nets and punkahs by individuals. In 1901, he fitted out another West African expedition to Lagos, which, owing to the unscientific, unpractical and unenthusiastic attitude of the government, was paid for by private philanthropy. At Lagos, the marshes were filled up with sand from the lagoons, wire netting for houses and cinchonization of individuals were instituted, and an annual subscription of £150 was obtained from the leading merchants for the organization of a mosquito brigade,

[8] Ross, *op. cit.*, p. 572.

[9] B. Grassi and A. Bignami, *Ann. d'ig. sper.*, Roma, 1899, N. S., IX., 258–264.

concerning which Ross wrote the first scientific treatise in 1902.[10] On the Gold Coast, in 1901, the streets were thoroughly drained, hollows in the ground were filled with rubble and earth, and all breeding places for mosquitoes were obliterated in 5,000 houses at Free Town. The British Bank of West Africa even opened a tropical sanitation fund. All this was accomplished through the propagandism of the Liverpool School of Tropical Medicine. But the crown of its achievement was to come at Ismailia, where, for the first time, assistance was obtained from the government itself. Ismailia, a sleepy, picturesque little town, on the shores of Lake Timsah, destined by De Lesseps to be the headquarters of the Suez Canal Company, was supplied with fresh water by a shallow canal from the Nile, built in 1877 and deepened for the passage of canal boats in 1882. This canal being further used to irrigate the desert and the outlying parks and gardens, much of the water ran to waste forming shallow marshes and ponds in and about the town.

> With the marshes came the mosquitoes; and with the mosquitoes came the fever, and with the fever came—the downfall.[11]

When malaria first appeared in 1877, there were 300 cases from August to December, out of a population of 10,000. By 1891, nearly 2,500 cases were reported and about 2,000 cases were treated annually. The town fell into decadence.

> Men, both Europeans and natives were unable to work, children were always ill, the death rate increased, while the birth rate fell. Every one was down with fever, and trade was soon at a standstill. The government offices were closed and were ultimately moved to Port Said.[12]

Ross arrived at the Suez Canal on September 12, 1902, in company with Sir William MacGregor, governor of Lagos, and immediately set about the task of mosquito reduction. The shallow pools and puddles the gardens and yards, and the cesspools under the houses were obliterated or treated with petroleum by the mosquito brigade, the marshes were drained, the canals and channels were cleared of reeds and other obstructions to flowing water, all water vessels, tubs and flower vases were emptied systematically, all breeding places of anophelines were visited and treated at stated intervals and penalties were imposed upon the townspeople who neglected to report faulty conditions. After an expenditure of 50,000 francs ($10,000), the anophelines were destroyed, and malaria disappeared, but an annual outlay of about $5,000 is necessary to keep the place healthy for "if the mosquito brigade stops work for a week, the mosquitoes return." The natives now call Ismailia "El turba e' nadeefa" (the clean tomb), because, like ancient Greece, it has never recovered from the blow dealt by malaria.

[10] Ross, "Mosquito Brigades and How to Organize Them," London and New York, 1902.

[11] Ross, "The Prevention of Malaria," Lond., 1910, p. 500.

[12] *Op. cit.*, p. 500.

Similar results were obtained at Port Said, Cairo, Khartoum, in Italy and Greece, in the Federated Malay States, in the West Indies, Panama, and elsewhere. In 1906, at the request of the Lake Copais Company, Ross investigated malaria in Greece, where the language itself created a natural bar to statistical information. He found a valley population of two and a half millions with 250,000 cases and 1,760 deaths. In 1905, there were 960,000 cases and 5,916 deaths. The average number of cases throughout the kingdom was 29 per cent. The Anti-Malaria League, founded by Constantinos Savas in 1905, has gone far toward making the ultimate control of the disease possible. Equally effective was the work of Angelo Celli and the Italian Anti-Malaria Society begun in 1899. As Sir William Osler wrote to the *Times* in 1909:

> In Professor Celli's lecture-room hangs the mortality chart of Italy for the past twenty years. In 1887 malaria ranked with tuberculosis, pneumonia, and the intestinal disorders of children as one of the great infections, killing in that year 21,033 persons. The chart shows a gradual reduction in the death-rate, and in 1906, only 4,871 persons died of the disease, and in 1907, 4,160.

Robert Koch's work at Stephansort, New Guinea, in 1900, turned a hotbed of malaria into an absolutely healthy colony by the exclusive use of quinine and his methods were successfully applied in the other German possessions. One great discovery of Koch's was the extraordinary prevalence of tropical malaria in children, which enabled him to attack the disease almost at its source. In 1902–5, Captain Charles F. Craig showed that intra-corpuscular conjugation in the malarial plasmodia is the cause of latency and relapses of the disease, whence it was shown that malarial fever can be transmitted by human "carriers," apparently free from the disease themselves. The discovery of the rôle of the *Stegomyia* mosquito in the transmission of yellow fever by Carlos Finlay (1881) and its scientific demonstration by Reed, Carroll, Lazear and Agramonte in 1900, led to the elaborate and successful prophylactic measures by the United States Army in Cuba and Panama, which included of course the obliteration of malarial fever. A full account of anti-malarial work in all countries is given in "The Prevention of Malaria" (1910) by Ross and his colleagues.

To sum up Colonel Ross's achievement in the science of infection, he devised his own methods for collecting, classifying, feeding, breeding and dissecting the mosquitoes investigated by him, located the species *Anopheles* as the probable true vector of malarial fever, showed that the moonshaped variety of the malarial parasites is found in the body of the *Anopheles,* that the spores of the parasites are concentrated, not in the intestines, but in the salivary gland of the insect, and that analogous parasites may be transmitted from bird to bird by mosquitoes, thus making it possible for Grassi and Bignami to prove conclusively that the malarial parasites develop only in the *Anopheles* and that the disease is

transmitted by this mosquito from man to man. Having demonstrated this hypothesis by induction, he then proceeded to employ his theorem deductively, as applied science, with brilliant success, in the prevention and eradication of malarial fever in West and North Africa.

Colonel Ross kindly gives the following personal reminiscences [sent to Dr. Garrison after General Gorgas's departure for South America, June, 1916].

As every one knows, the Americans started their important sanitary work at Panama early in 1904 under the distinguished management of Colonel (now General) Gorgas, U. S. Army. He invited me, on behalf of the American government, to visit the Canal Zone in order to witness his measures, and as I was also asked to read a paper at the Congress of Arts and Sciences held in connection with the great Exposition at St. Louis, 19th–25th September, 1904, I determined to visit Panama after the Congress was over. At the end of the Congress, each of us who had read papers was given the sum of five hundred dollars to pay for our expenses in traveling over to St. Louis and returning, and we pouched this sum in notes with considerable satisfaction. Unfortunately many of us had scientific friends in the states, and I fell into the clutches of Dr. (now Sir William) Osler who swept me off to Baltimore. After a very warm time with him in that city, I fell into the hands of other friends who passed me on from Philadelphia to New York and left me so little leisure to spare from hospitality that I could not get my five hundred dollars banked or converted into an exchange note. I was then rushed on board ship where I met Colonel Gorgas himself (who was not going to Panama with me) and was duly photographed and speeded on my journey with the good wishes of my many friends. A week later, after a delightful voyage, I arrived in Colon with my five hundred dollar notes still in my pouch. We were immediately sent across the Isthmus and arrived at Panama the same evening. The weather was extremely hot, with the usual result on my nervous system that I became very sleepy and lazy. On arrival at Panama, I was ushered into the Medical Officers' Mess. Now this was a teetotal mess, and I am not a teetotaller by profession, though, I hope, always very moderate in my devotion to god Bacchus. They gave us beef-steak and iced water for dinner, and I became so extremely sleepy after this diet that when I went to my sleeping quarters in a house near the hospital, occupied by Captain Lyster, United States Army, I determined to go to bed at once (within my mosquito netting) and sleep off my fatigue. Lyster did the same thing and we slept beautifully all night. Unfortunately I was so overcome with the beaf-steak and the iced water that I left my pocket book containing my five hundred dollars on the table at the foot of my bed, though fortunately I kept my watch in the pocket of my sleeping jacket. There was a considerable wind all night which kept the doors slamming or creaking, and I was too indifferent to the world to care what happened. When we woke in the morning we were entirely refreshed and as strong as lions in consequence of the beef-steak; but Lyster ran in to my room with alarm written on his face. Sure enough my clothes had been thrown about the room in a terrible manner and my cigar case was found empty in the bathroom. He said that his best suit of blue serge clothes had unaccountably disappeared. We presently heard wailings from all round, and Dr. Balsch, the Health Officer of Panama rushed in from the next house to say that his valuable gold watch had gone. Then I bethought me of my five hundred dollars and ascertained that my pocket book had also disappeared entirely. The fact was that all our houses had been raided that night by an expert gang of house-breakers, who had taken my money and the numerous valuables from my friends.

I was not worried about my loss, because, fortunately, I had asked my agent in England to put a sum of money at my disposal in case of need with a New York bank. Hence, though my friends offered to give me any cash I liked, I refused their offers, and lived for a week in Panama entirely on hospitality with the assistance of a few dollars in my breeches' pocket. Really I was never more happy in my life, and felt the complete joy of being an absolute pauper. At the end of my visit I went on board the same ship, which was to take me back to New York. As I had no money on board the ship I remained equally happy during the voyage, but just as we reached New York my sole remaining hat was blown into the sea. I therefore arrived at New York on a Saturday, with one dollar in my pocket and no hat. Nevertheless I presented myself at the Waldorf-Astor Hotel and asked them to take me in on credit only till Monday. They lent me some cash to buy a hat and fed me as if I had not been a pauper at all. Next Monday my happiness ceased again, because the bank accepted my credit-note from London and filled my pockets with the detestable stuff on which we live.

I believe that none of us ever got back our losses, but the fun of the business repaid me. I believe that I was the only pauper who had ever been the guest of the Great American Republic.

I say nothing here of the extremely interesting time I had in Panama. My only grief was that Colonel Gorgas was not with me; but Captain Lyster, Dr. Balsch, Colonel Carter, Dr. Ross, Mr. Le Prince and every one else gave me the best time imaginable, but generally on a teetotal basis! I ascribe my loss entirely to the somnolence induced in me by teetotalling, and have abandoned that calling ever since.

The most bitter irony of the business was that, when I arrived in Liverpool, my friends there refused to believe that my five hundred dollars had been stolen at all and averred that it had all been thrown away in wild dissipation with Sir William Osler and other congenial friends, so that I obtained the reputation of being, not a teetotaller, but a wastrel.

RONALD ROSS

26th June, 1916.

Ronald Ross is a man of remarkable versatility. He is not only a parasitologist and sanitarian of proven abilities, but also a mathematician, a poet and a publicist. He is editor of *Science Progress,* and one of the editors of *Annals of Tropical Medicine.* In 1905, he introduced his method of solving equations by "operative division,"[13] a modification of that discovered by Michael Dary, a gunner of the tower of London, on August 15, 1674, and communicated by him in a letter to Newton on that day. The rationale of this method consists in expressing an algebraic operation as a "verb function," an action upon or arrangement of quantities, without stating the quantities themselves. It is thus one of the symbolic or substitution algebras which have played such a prominent rôle in modern mathematics. Ross defines an algebraic operation, some particular grouping or arrangement of quantities, as a verb, while a function, the result of such grouping, is definable as a substantive or noun. He holds that this notation gives the power of expressing any algebraic operation without reference to the quantities employed, *e. g.,* if o denote

[13] Ross, *Proc. Roy. Irish Acad.,* Dubl., 1905, XXV., Sect. *A,* No. 3, 31–76.

an operation as a verb function, then o^n will denote the operation of raising a quantity to the nth power, when $[o^n]x = x^n$, and since o^0 is unity, $[ao^0 + bo^1 + co^2]x = a + bx + cx^2$. In all this, Ross modestly regards himself as an amateur, but he believes that Newton himself may have adapted Dary's principle in devising his own method of obtaining the roots of equations by approximation. In Ross's operative division, each term of the quotient operates on the whole divisor instead of being multiplied into it, as in ordinary algebraic or arithmetical division. The rest of Ross's mathematical work has been concerned with "pathometry," a term of his invention signifying the quantitative study of parasitic invasion and infection in individuals or groups of individuals. He has investigated, for instance, the variations of mosquito-density in relation to time and place, the relation of mosquito output to extent of breeding surface and the relations of mosquito-density to the rate and extent of malaria-incidence in a given locality; also the relation of malaria-rate to such factors as parasite-rate, spleen-rate (number of malarial cases with enlarged spleen), fever-rate, and the proportion of people who are constantly ill from malarial fever, all of which are lessened by "mosquito reduction." This work on mosquito distribution is said to have been the inspiration of the mathematical memoir of Pearson and Blakeman on random migration. Latterly, Colonel Ross has occupied himself with the study of epidemic curves, that is, the graphs predicting the course and probable duration of an epidemic from its initial data, which were first investigated by the English statistician, Dr. William Farr, in 1866. Work of this kind has been attempted only within the last sixty years, the explanation being that there have been few vital and medical statistics covering large averages until recent times. In the eighteenth century, Daniel Bernouilli applied the calculus of probabilities to smallpox epidemics and got an equation giving the number of survivors who have not had the disease in terms of the number surviving at a given age out of a given number, the number attacked and the number not attacked in a year. The recent aim has been to discover the law of which an epidemic, in relation to space and time, is to be regarded as an expression. In other words, while the hygienist aims to influence and limit the course of the epidemic by such coefficients as vaccines, sera, destruction of insects or animals carrying the disease, or other aggressive sanitary measures, the aim of the modern epidemiologist is statistical prognosis or the prognosis of infectious disease on a grand scale. The strong point made by Farr was that the theoretical curve of an epidemic in space and time is a normal curve. The generic idea is that all recurrent natural phenomena, *e. g.*, the weekly ratio of illegitimacy to the normal birthrate in a large city, tend to acquire a certain uniformity. Farr's law states the general epidemiological principle that subsidence

along a definite line is a property of all zymotic diseases. During the cattle plague of 1865–6, Mr. Lowe in the House of Commons (1866), predicted an epizootic of tremendous proportions, with a formidable rate of increase. His views were controverted by Dr. William Farr in a letter to the *Daily News* of February 17, 1866,[14] in which it was maintained that the rate of increase would begin to decrease rapidly at a certain point, after which it would go on decreasing until the rate of incidence itself decreased. This generalization, the facts of which are not unlike the phenomena of depopulation in modern states, is known as Farr's law. It implies, as Farr says, that "the curve of an epidemic at first ascends rapidly, then slowly until it attains a maximum, then makes a turn and falls more rapidly than it mounted." To prove his case, Farr plotted a bell-shaped probability curve of the actual epidemic, based upon reported and calculated statistics, and predicted that it would have an early maximum with a rapid decline, ending in June, 1866. Actually, the epidemic rose to a maximum on February 24, a fortnight earlier than Farr had predicted, but subsided in the early summer, as he surmised, although at a slower rate than his curve indicated. Nevertheless, his calculations, in the face of the public alarm obtaining at the time, were a great advance in epidemiology, what Ross calls "the first *a posteriori* work on epidemics," in which it was attempted to work back inductively to underlying principles from observed and observable data. Farr also applied his principle with success to a subsequent smallpox epidemic. The cause of the constantly decreasing increase has been sought in the gradual lack of susceptible or infective material, *e. g.*, in the effects of vaccination on the Boston epidemic of smallpox in 1721, a view favored by Ross. Another cause, favored by Brownlee, is to be found in Pasteur's theory of attenuated viruses. Pasteur showed that the pathogenic properties of a virus may be increased or attenuated by successive passages through the bodies of appropriate animals, from which he reasoned that the origin or extinction of an epidemic disease may be due to the strengthening or weakening of a virus by environmental conditions, either in external nature or in the bodies of animals. This seems borne out by the thermodynamic conditions governing the virulence of microorganisms. In the bodies of bacillus carriers, the typhoid bacillus is temporarily inactive or inactivated, for the nonce, an insulated "adiabatic" system, in that energy can neither go in nor out of it. In the body of a susceptible person, the same bacillus becomes activated and pathogenic, whence it is reasoned that a nonvirulent strain of a bacillus may become pathogenic under certain conditions in nature. In this way, Sudhoff has attempted to explain the origin of syphilis in Europe. Prior to its appearance as such, in 1494, there had existed a class of lepra-like diseases yielding to mercury, as is shown by old Italian prescriptions of

[14] Reprinted by Brownlee in *Brit. M. J.*, Lond., 1915, II., 251.

1465. These diseases Sudhoff regards as foci of an endemic spirochetosis, which, in persons rendered weak and susceptible by wars, famine and debauchery, became a virulent infection. Sydenham saw European syphilis as a mode of West African yaws, and salvarsan is a true *therapia sterilisans* for the spirochete of yaws. Pasteur's law explains the facts about the great plague of London (1666). When the disease began to abate, vast numbers of people who had fled the city returned, and Pepys, in his "Diary," made anxious predictions as to a possible recrudescence of the epidemic. But this was not the case. The plague had worn itself out, and it is said that some even occupied the beds of plague patients with immunity.[15] Yet, while lack of susceptible persons and attenuation of the specific virus are not identical causes, they may sometimes amount to the same thing. Since Farr's time, mathematical investigations of epidemics have followed two main lines. Brownlee, Greenwood and other English statisticians have applied the skew curves, devised by Karl Pearson, to the analysis and gradation of the statistics of various epidemics, and Brownlee has found that most of the curves evolved are symmetrical bell-shaped curves of the Farr type, with the difference that the curves do not fall more rapidly than they rose, as in Farr's original hypothetical curve of 1866, but more slowly, as in the actual figures of his 1866 epidemic (Pearson's type IV. curve).

Ross's investigations have followed the lines laid down by himself in 1904, and his ultimate aim is to account, not only for the epidemics which have a symmetrical or normal curve, but also for the asymmetry which characterizes many epidemics influenced by external forces. He divides infectious diseases into three classes: "(1) diseases like leprosy or tuberculosis, which vary little from month to month, but may slowly increase or decrease in the course of years; (2) diseases like measles, scarlatina, malaria and dysentery, which are constantly present in many countries and flare up as epidemics at frequent intervals; and (3) diseases such as plague or cholera, which disappear entirely after periods of acute epidemicity." Concerning the diseases of the second class, he inquires whether they may be due to "a sudden and simultaneous increase of infectivity in the causative agents living in infected persons, or to changes of environment which favor their dissemination from person to person, or merely to the increase of susceptible material in a locality due to the gradual loss of acquired immunity in the population there." It is known, for instance, that measles has occurred at Perth regularly every sixteen months during the last forty years, with but two variations; in Glasgow, every fifteen and a half months up to 1800, and every twenty-four and a half months from 1855 on; while the London records of measles during 1840–1912, indicate a periodicity of about 1⅞ years.[16]

[15] J. Brownlee, *Proc. Roy. Soc. Edinb.*, 1905–6, XXVI., 486.

[16] *Brit. M. J.*, 1915, II., 652.

The coefficients which Ross introduces are the measures of variation due to mortality, natality, immigration and emigration of the non-affected and affected persons respectively. From a set of equations containing these coefficients, the total population and the ratio of the affected to all its members, he gets an equation giving the proportion of the total population affected at a given time.[17] The curve of which this equation is an expression is, in the simplest case, the regular bell-shaped curve, in other words, the assumption that the infectivity ratio is constant or proportional to the number of persons affected gives curves which are not irreconcilable with the hypothesis of decline from exhaustion of susceptible material, opposed by Brownlee. These studies in "à priori pathometry," still to be completed, give Ronald Ross a distinguished place in the modern English school of iatromathematicians.

In 1906, there appeared a little volume of verses with the title page "In Exile, by R. R. Privately Printed," of which the author says, in his preface,

> These verses were written in India between the years 1891 and 1899, as a means of relief after the daily labors of a long, scientific research.[18]

In a sympathetic review of this book, Dr. Weir Mitchell, a fellow medical poet, has said:

> In any climate and under the most indulgent conditions, what he did would have been remarkable. In India the lack of sympathy on the part of his military superiors, abrupt army orders, limited means and absence of help seemed ever ready at his happiest approach to success to mock him with delays. He must have felt as if, at times, some malign fate stood ready with obstacles over which no energy, no self-assurance of ultimate victory could prevail. I know of no medical story more interesting, no research which so surely found what it exacted, that heroism back of which lay energizing sense of duty. . . . Ronald Ross, when half blind or exhausted with work, turned to verse and sought in a difficult field for the relief that change of mental occupation affords, for the making of good verse is not an easy occupation, as several of the greatest poets have confessed. This little book is an interesting record of moods of mind, of hope, despair, sorrow and final triumph. It gives one a vivid conception of the effects of exile, personal losses and the torment of tropical conditions on a man with an imagination of high order, somewhat lacking for use in verse that which only much technical training can supply. There are many verses in this book which exacting self-criticism might have altered or left out. There are some easily amended defects of rhythm—verses which are needlessly obscure; but these concern me little. There are many quatrains of virile power, descriptions of eloquent force or notable passages of insight and deep feeling.[19]

Of Ronald Ross's poems, space permits the citation of but one, the

[17] Ross, *Proc. Roy. Soc. Lond.*, 1916, Ser. *A*, XCII., 207; 211 et seq.

[18] Colonel Ross has recently presented to the Surgeon General's Library his youthful dramas "Edgar" and "The Judgment of Tithonus" (Madras, 1883), "The Deformed Transformed," and the following books of original verses, viz., "Philosophies" (1909), "Fables" (1907), "Lyra Modulata" (1911) and "The Setting Sun" (1912).

[19] Mitchell, *Jour. Am. Med. Ass.*, Chicago, 1907, XLIX., 852.

verses written on the day upon which he discovered the malarial parasite in the body of the mosquito:

This day relenting God
  Hath placed within my hand
A wondrous thing; and God
  Be praised. At his command.

Seeking His secret deeds
  With tears and toiling breath
I find thy cunning seeds,
  O million-murdering Death.

I know this little thing
  A myriad men will save.
O Death, where is thy sting,
  Thy victory, O Grave!

Before Thy feet I fall,
  Lord, who made high my fate;
For in the mighty small
  Is shown the mighty great.

In his work as a sanitarian and eradicator of disease, Sir Ronald Ross has waged valiant and efficient warfare against the indifference and apathy of organized governments toward applied science, that medieval frame of mind so well described by Sir Clifford Allbutt:

> We find, in ruling classes, and in social circles which put on aristocratical fashions, that ideas, and especially scientific ideas, are held in sincere aversion and in simulated contempt.

Time and again has Ronald Ross returned to the charge in his general assault on unscientific administration in regard to the prophylaxis of infectious disease. His utterances on this theme reveal him as a publicist of large-minded type. Nothing seems more characteristic of the man than his general view of the whole matter:

> Probably few any longer accept the teaching of Hume, that the object of government is no other than "the distribution of justice." The function of an ideal civilized government might be described as the performance of all acts for the good of the public which individual members of the public are by themselves unable to perform—that is, the organization of public welfare. The individual can certainly add much by intelligence and virtue to his own welfare; but these qualities do not suffice to protect him altogether against those evils which can be combated only by concerted action, such as the depredations of disease and of external and internal human enemies; and where he is powerless, the government, and only the government, can help him. Now such concerted action is likely to be successful only when it is based on sufficient knowledge; and a scientific administration differs from an unscientific one just in this particular, that it seeks the necessary knowledge, while the other acts blindly. In nothing is this more manifestly the case than in connection with that department of public administration which is charged with the protection of the public against disease—a department second to none in importance, because it concerns not only our sentiments and our pockets, but our health and our lives.[20]

[20] Ross, *Nature*, Lond., 1907, LXXVI., 153.

WAR SELECTION IN THE PHILIPPINES

BY DR. EDWIN BINGHAM COPELAND

DEAN OF THE COLLEGE OF AGRICULTURE, UNIVERSITY OF THE PHILIPPINES, LOS BANOS, LUZON

IT has been assumed by writers on the relation of war to racial development—and I am sure the assumption is correct—that fighting has at some time been necessary to keep up the quality of the race. Some kind of struggle, war or economic competition, or something of this kind, must have been necessary to maintain human progress from the time that man acquired such a mastery over the rest of nature that he was spared the necessity of a real struggle with other animals. I have had the impression from some of the early papers of Dr. Jordan that he granted the correctness of this assumption, but believed that modern warfare was peculiar in not having this selection value. This would have implied, even if it were not stated, that the wars of ancient but historical people did have a selection value. This is explicitly denied in "War and the Breed," and is certainly denied with right. In the wars of the Greeks, selection of the best by survival was probably even less likely than it is in the present European war. In the warfare of to-day, the best are eliminated both because they are admitted to the army, and because the brave ones sometimes get a chance to expose themselves; but in the present warfare, there is so little chance to select the enemy to be killed, that the picking of the victims is essentially without any choice whatever. In the warfare of the Greeks, even leaving the Spartan out of account, social custom drove the good citizen to war and forced the brave man to expose himself at almost every opportunity. The brave or the strong man was driven by the full force of social pressure and by his own sense of honor to take every possible risk, and this, of course, eliminated the best more rapidly than would be done by the present war. Beyond this, the man of ability was most dangerous to the enemy, and as a general proposition, there was particular glory to be acquired by killing a notable foe. This placed the best warriors at a considerable disadvantage as compared with their present position.

I note a passage in Thucydides. The Athenians captured a considerable body of Spartans on the Island of Sphacteria. Some of the Athenians were deriding one of the captives and asked him if the ones who had been killed had not been braver men. The captive replied that it would have to be a very wise arrow which could distinguish the brave from the cowardly. His comment would place warfare where it is today, an indiscriminate slaughter of the combatants.

I have had considerable opportunity during twelve years in this part of the world to see the effect of warfare of various kinds on the race. It seems to me that we have in the Philippines illustrations of both

good and bad racial effects of fighting. Our Moro population is one which has made fighting its chief business for centuries. The Moros entered the Philippines in the fifteenth century, and for the 450 years since that time they have not done much except fighting. Because of the school of ethics in which they are brought up, they are the best fighters in this part of the world. Give them the same weapons and they would be practically certain to overcome an equal number of Filipinos. At any rate, if both sides were given primitive weapons, this would be true. From such evidence as we have, it seems safe to conclude that four or five centuries ago, the Moro was the best man in the Philippines in almost every respect. To-day, he is decidedly the inferior of the Filipino for every purpose except fighting. I will make this general statement without any reservation in spite of the fact that the Island of Jolo had a bigger percentage of the population able to read and write fifteen years ago than did any Christian province in the Archipelago. The Moro is uniformly physically inferior to the Filipino, and this is true of both men and women. It is not altogether the Moros' fault that the development of schools has been very backward in the Moro province, but I have had enough experience with individuals to conclude, for myself, that the Moro of to-day is intellectually inferior to the Filipino. Another effect of centuries of fighting is that there is a very conspicuous tendency to prompt degeneration when war is stopped. When the Moro is kept from fighting, as has happened in certain districts, notably around Zamboanga, and is given the same opportunity which the Filipino has had in most places to develop industrially, instead of doing this he becomes as worthless as a human being can be. It may still prove to be possible to develop the Moro industrially, but it is a certain fact that he makes practically no start at all in developing himself. It is this degeneration when the fighting ceases which I would call the most conspicuous evidence of the destructive effect of centuries of fighting. As a matter of opinion merely, I would say that the Moro will admit of being developed. It is my impression from living among various people, that there is very little difference in their susceptibility to development and, to this extent, I believe that even the bad effect of warfare can be overrated. War does more damage by far in removing those who could be leaders in development, and cutting off the capacity for leadership from the following generations, than it does by lowering the capacity for being developed of the body of survivors.

But, we have in the Philippines still other races than Moros and Filipinos. Among these are the Negritos, about whom I know very little. Possibly they are low enough in the scale of humanity so that they can not be developed as well as most people can be. But there are in the mountain districts of Luzon and Mindanao so-called wild people, pure pagans, who have through all the centuries fought among themselves, just as primitive men must have fought through ages, practically

without firearms; and among whom warfare is either hand to hand or with projectiles which are aimed at individuals instead of masses, so that the essential elements of individual combat are still present. Physically, these wild men contain the best people of the Archipelago. Judged in another way, by the strictness with which they observe their own ethical "code," they are also better than the Filipinos. This strictness in observance of the tribal customs is always a function of conditions of constant struggle. In this respect, the pagan and the Moro are alike and the Christian is inferior, because, during the recent centuries, he has been largely spared the necessity of tribal struggle for existence. As to intellectual ability, we have not enough information about the wild men to justify valid conclusions. There have been in recent years a few Igorots of different tribes who have acquitted themselves excellently as students. I have also known Bagobos, and Mr. Elmer reports a different tribe from Mindanao, who have seemed to us to demonstrate decided intellectual keenness in their dealings with nature. But the fact that the Bagobo is keener in dealing with nature than the Filipino may reasonably be the result of his being placed where he has to be keener. Almost every American who has considerable contact with the Igorot regards him as the best man in the Philippines. Knowing both Igorot and Bagobo, I am disposed to rate the Bagobo of the hills above the Igorot. On the other hand, men thrown in intimate contact with the better class of Filipino scout the idea that the wild man of any kind can be compared with the Filipino. Leaving these opinions as matters of mere opinion, the fact is indisputable that the wild man is physically the best there is in the islands to-day. This superiority is not a function of the altitude. Lukban, for an instance, is an excellent Filipino town, and Lipa is another. These are in altitude between the Bagobo settlements of Sibulan and Todaya. The Bagobos could pick the Filipinos to pieces with their bare hands. There is an old Latin proverb which says that a sound mind goes with a sound body, and I am inclined to believe that their mere physical superiority, even reduced to nothing but better health, would give to Bagobos an advantage in fair intellectual competition, with equal preliminary training, with the Filipinos. To at least this extent, it is my opinion that we have among our wild people evidence of the positive value of personal combat, when the struggle for existence takes this form, as a means of racial improvement. These suggestions are of course sent merely as matters of collateral interest as possibly throwing some light on the outer edges of a big subject.

It thus appears that the Moro originally excelled the Filipino in ability; but has become distinctly inferior, physically and in ability to develop in civilization, as a result of several centuries of chronic war. The Bagobo and Igorot (in the broad sense) exemplify the good results of selection by primitive war on the scale of personal combat.

In this article, I do not venture, however, a prophecy that the

Bagobo will ever demonstrate any kind of superiority to Filipino or Igorot. The demonstration depends very much upon opportunity. The Igorots, in the broad and rather inaccurate sense in which I have used the words, are a numerous people capable of maintaining a large measure of independence; and they are now receiving what I believe is competent and efficient help in preparation for intercourse with the outside world. The hill Bagobos are few in number and the interference of government in their affairs has not, in my opinion, been very intelligently calculated to preserve them as a strong race. What the government undertook to do, with the best of intentions and with full recognition of the superior vitality of the Bagobo, was to bring him in contact with civilization by bringing him down out of the mountains. I have not seen these people for a number of years, but could anticipate no result of this policy except that most of the Bagobos would become plantation serfs and the more independent minority would become renegades. This was the work of Lieutenant Bolton, one of the men most conspicuous in devotion to the interests of the people under his charge whom I have ever met. The best of intentions may make the most mischief in the attempt to make a race over and improve its conditions without sufficient appreciation of the fact that the direct ability of the race is adapted to the conditions under which this ability has been developed. Lieutenant Bolton was murdered a little later as the result of another attempt to make a powerful savage into a man of influence under more civilized conditions.

We have naturally made mistakes of the same kind in the well-meant attempt of many of our officials to make good Americans out of good Filipinos. The preservation of order in these islands during the past fifteen years has of course been of tremendous value to the people, and the introduction of a general educational organization, even of such an organization patterned very largely after that of the United States, has been another incalculable service. But the transplanting of a scheme of government, including even features of exceedingly doubtful value in America, has brought with it evils some of which will probably never be peacefully outgrown.

These comments are, of course, not relevant to the question of racial selection. They have, however, a bearing on the conditions which make war the foremost subject of world interest at this time. I am a great admirer of real German culture. I have a certain sympathy with the German ambition (even if its profession by the government may be largely hypocritical) to germanize other parts of the world. The trouble with the scheme, aside from its probable impracticality by the methods being tested, is that what is best for Germany is not necessarily best for England and Borneo, any more than what is best for the United States is necessarily best for the Filipino, or what is best for the Filipino is best for the Bagobo.

ESSENTIALS IN THE STUDY OF LABOR ORGANIZATIONS

By Professor FRANK T. CARLTON
ALBION COLLEGE

THE assumption that all labor organizations may be traced back to some one original form of local trade society is unwarranted. Labor organizations of different types and located in different communities are the products of environmental conditions and forces which have caused the wage-earners to cohere in some weak or strong form of union organization. Because of increasing population, the elimination of free land, rising prices, or other social phenomena, American wage-earners have been vividly impressed with the insufficiency of individual bargaining. Organization is naturally the next step. Wage-earners organize in order that wages may be raised, hours reduced, or conditions of work improved. The form of the organization is not the significant fact; nor is the expressed function of the union whether business, revolutionary or "predatory" of great importance But classification may help students of labor problems in their effort to investigate the complex of union origins, structures, methods and functions.

Organized labor is a social phenomenon; it is a form of institution. The form, methods, ideals and immediate purposes of labor organizations may be studied in the same manner as political parties or fraternal organizations may be analyzed. A union consciously or unconsciously adopts a certain peculiar form or structure in order to aid it in accomplishing certain aims. No institution would come into being were it not intended, deliberately or fortuitously, to affect certain changes in the course of human affairs. And no form of organized labor would exist unless wageworkers hoped to obtain through its agency some improvement in living and working conditions. These statements are certainly little short of axiomatic. In short, both the structure and functions of a labor organization or of any other institution are the visible and tangible results of underlying forces and causes which spring out of the physical and social environment. The analysis of a labor organization is a study in social mechanics. To classify labor organizations according to structure or according to functions may be desirable; but the classifier should remember that he is only dealing with outward manifestations and results, not with causes and fundamental motives.

The union—a social structure or organization—is a grouping of wageworkers for the purpose of accomplishing certain results. The union is a tool; a means to an end. Writers upon the subject of labor and labor organizations have not held that the form of organization was fundamental. Nor have they held that all labor organizations were alike or even similar in ideals and plans. Indeed, quite the contrary is true.

Students of government realize that the term—"a democratic government," for example—must be translated differently in Haiti than in the United States. Nevertheless, classification of governments into republics, constitutional monarchies, and so on, is of value to students of political science. It is doubtless true in a broad way that democratic forms of government are the products of the change known as the industrial revolution. But the existence of danger from outside foes may retard progress toward a democracy, as witness Germany. Or tradition may keep the shell of a government for a long time after its reality has been sloughed off, as is the case in England. In like manner, opposition from without, tradition, or the pressure of leaders, may greatly modify the course taken in evolving the structure and functions of a labor organization.

In the great majority of cases, a given structure or form of a government or of a labor organization more truly represents a past than a present balance of forces; but it is also a factor in determining the present-time attitude of those adhering to the government or labor organization in question. After an institution has been developed and has crystallized into certain forms, this somewhat inelastic structure usually serves as a modifying and conserving force or influence. Group and institutional inertia must be reckoned with in any study of social and institutional forms. American legal and constitutional forms have greatly modified the course of events in American national life. The existence of social customs and habits also tends to prevent rapid changes in ideals. The psychology of the American has undoubtedly lagged behind the unusually rapid changes which have taken place in industry during recent generations. The American workingman has been too individualistic to cope effectively with the great and steadily growing combinations of capital; to many of them yet clings the restless and impatient vitality and self-assurance of the frontier. The effect of social inertia is also plainly visible in the ideals, the concepts and the psychology of the unionist. The psychology of the average unionist is still measurably affected and modified by ideals and concepts crystallized during the outgrown era of small-scale, non-integrated industry. Again, overworked and undertrained workers will have a narrower vision than more efficient and better trained workers. A union composed of the former will be more erratic and less calculating than one composed of the latter type of unionists.

Slavery and serfdom are heritages which the past offers to the wage-earning class of to-day. The prevalent idea that the employee is the "protégé" of the employer is old and dies hard. Organized labor is, in fact, a token of emancipation. In struggling upward toward industrial democracy the workers are seriously hampered by the lingering and still potent ideas and ideals developed during generations of subordination and of non-citizenship. As a consequence, the evolution of the psychology of the wage-earner—the new social psychology—is retarded and

modified by the old and outgrown folkways as to the relation between employers and employees. It is also affected by survivals in the form of rabid and irrational national patriotism, racial antagonisms and concepts as to the desirability of different forms of work and service. The European war conclusively proves that in times of national stress the old catch-words and phrases are more powerful and compelling than the newer ones of social solidarity and loyalty to the working class. But at other times when the life of the nation is not menaced, the phenomenon of union loyalty bulks large among the members of organized labor.

Both the specific structural and the specific functional forms of labor organizations are very diverse. No two types of workers have been subjected to exactly the same economic pressure, the relations between workers and their employers vary greatly in different lines of business, the possibility of displacement by other workers or by machines likewise varies from trade to trade and from occupation to occupation, and price levels and standards of living are subject to rapid modifications. This complex situation is further complicated by the institutional lag exhibited by organizations of labor. And the influence, conservative or radical, of the capable and aggressive leader, must not be neglected. Samuel Gompers, for example, is a factor which can not safely be overlooked in any careful consideration of the evolution of the American Federation of Labor. The autocratic and imperious leader has played an important rôle in labor organizations as well as in the affairs of nations. The appeal to the passions and emotions figure in union matters as well as in party politics.

As a consequence, labor organizations present to the student and to the man-in-the-street a bewildering diversity of structure and of functions. Some of the apparent variations are not real. These are due to the idiosyncracies and preconceived notions of would-be interpreters of unionism. But inevitably the variations are many, because these register the results of the play of a multitude of pushing and pulling forces. Yet, the fundamental desires and motives are comparatively simple.

The growth of trade-unionism and of what is called the trade-union spirit is a concomitant of industry organized after the manner of a machine process.[1]

The term "machine process" does not, however, necessarily mean the actual use of machines, but it may be applied to all large-scale methods involving wide market areas. As different workers come in touch very differently with the machine process, variant ideals may be expected to appear. This differentiation becomes clear when a comparison for example, of the cigarmakers with the locomotive engineers, or of the machinists with the building trades workers, or of the molders with the migratory workers, or of the miners with the barbers, is undertaken.

[1] Veblen, "Theory of Business Enterprise," p. 327.

Individuals may be animated by altruism and act contrary to their own welfare and happiness in the interest of others; but groups, classes and nations do not. At least, such is the situation up to the present time.[2] Frequently, however, the interests of a group, class or nation may on the surface appear altruistic. And when group interest and altruism run in parallel channels, the emphasis is always placed upon the latter. The selfishness of groups is no new discovery of the social psychologist. Practical politicians have for years and probably for centuries recognized the potent influence of group selfishness. One example may be cited from American history. In 1828, Mr. McDuffie, a well-known South Carolinian, said:

> Individuals are always open to impressions of generosity. But classes of the community, and sections of country, when united and stimulated by the hope of gain, being destitute, like corporations, of individual responsibility, are, like them, destitute of hearts and souls to feel for the wrongs and sufferings they inflict upon others.

Organized workers, like organized capitalists, are organized primarily for group or class betterment. All methods and ideals must stand the acid test of group advancement or retardation. However much we may dislike to look the facts in the face, they will not down. Workers are men and women like employers and animated by the same fundamental human animosities and desires. And the division of unionists into revolutionary and business groups is only one of degree and circumstance. There are in fact no fundamental differences. A so-called business union may under pressure of adverse circumstances become within a few years revolutionary. Or, the reverse change may take place, and a revolutionary labor organization may gradually become more and more conservative under the mollifying touch of prosperity.

Miss Marot[3] has frankly and boldly stated the real demand of the unionist, be he of the business or of the revolutionary type. It is for less work and more pay. This statement from a spokesman of organized labor discloses a clear and distinct line of cleavage between the working-class unionist and the middle-class reformer. But this frank statement rings true whether it be applied to the aristocrats of labor or to the ranks of the unskilled and readily replaceable. Eliminate cautiousness and lack of vision of the goal, and the conservative unionist reveals the same essential longings and desires as his more impulsive and radical brother. And, furthermore, he is not essentially different from his employer who demands more profits without questioning whether more profits mean more or less service to the community.

The attitude of the radical or revolutionary union is well illustrated by a trade union in one of the large western cities. The members of this strong union "recognize no trade or industrial obligation

[2] For a somewhat different view, see Cooley, "Social Organization."

[3] "American Labor Unions," p. 4.

above their allegiance to fellow unionists or to labor. They consider that their contract to stand by labor comes first and takes precedence over all contracts made with capital."[4] Allegiance to the union is placed on a par with national patriotism. No contract obligation is allowed to stand in opposition to group welfare and group requirements. This revolutionary attitude is assumed not only by industrial unions but by organizations of the familiar type of trade unions. The viewpoint of these unionists is similar to that of a nation which is ready to tear up a treaty when confronted by what is considered to be national necessity. Class lines are often drawn as taut as are national lines in times of stress and strain.

On the other hand, conservative railway brotherhoods are ready in case of a strike to counsel a policy of non-interference. But the members of the railway brotherhoods who are conservative and who are very explicit in stating that they do not intend to disturb the present industrial order, are in spite of external characteristics not very dissimilar from the members of radical unions who are extremely bitter in their denunciations of existing conditions, and who are "revolutionary." The difference between the viewpoints of these two classes of unions is not to be explained by resorting to some more or less occult statement of group or social psychology. But it is to be found by analyzing the different economic environments in which the groups work and live, and the different kinds of economic and social pressure to which the groups are subjected. The members of a railway brotherhood occupy a strategic position. It is very difficult to obtain reasonably efficient substitutes in case of a strike. But a union of unskilled men would perforce be obliged to take another stand or suffer their places to be filled by strikebreakers. Put the railway brotherhoods face to face with the menace of the green hand, or with a hostile employer who is nibbling at wages and who refuses to consider granting a standard wage, eliminate their systems of insurance, put the members of these brotherhoods in the position of many another group of wage-earners, and the present much-approved set of ideals will rapidly be replaced by others not so conservative.

Subject the railway brotherhood to the dangers which are and have been for several years confronting certain radical old-line trade unions, and their conservatism and the emphasis now placed upon the sacredness of contract will disappear with celerity. The early history of that much maligned organization, the Western Federation of Miners, furnishes a fine illustration of social transformation. The metal miners of the far west were

confronted by a quickly developed and aggressive class of wealthy mine owners. Control of the mines was suddenly centralized; individual bargaining became futile; the separate and disunited units of labor were sweated. The miners felt

[4] Marot, "American Labor Unions," p. 14.

themselves to be in the grip of a new and strong industrial system. . . . Under pressure, the miners knit together into an industrial class—conscious and avowedly socialistic union; and, remember, these miners were individualistic American frontiersmen.[5]

It must, of course, be admitted that the experience of the unskilled worker with the machine process will modify his viewpoint somewhat and make him more susceptible to influences which cause the growth of group or class solidarity.

The structure of the American Federation of Labor and its constituent parts is gradually changing. This modification is not due primarily to a new group psychology. It is, however, true that the mixture of racial elements in the Federation is somewhat different than it was ten years ago. Nevertheless, the significant factors are the changed industrial situation, the reduction of many kinds of workers to a common denominator by the use of the machine, the fierce opposition of employers, and the like.

The form of organization is indeed no minor matter. The trade union is an antiquated weapon in the fight against the big corporation unless the skill of the trade is still a potent factor or some other special place of vantage remains. To meet the mighty German army with the weapons of the Civil War spells ignominious defeat. To combat for higher wages and shorter hours with the defenses of 1866 likewise means defeat. The trade union is the fundamental and most natural grouping of workers for betterment. In the trade union are united workers engaged in similar work and interested in similar matters. Carpenters have more in common with other carpenters than with boilermakers or molders. But as the machine process undermines trade after trade and tends to reduce all workers to a common denominator, trade or craft becomes of less and less importance. And as carpenters, molders and boilermakers become united as employees of the same corporation, trade lines yield to the unity of interests as employees of one big business organization. As a consequence, organization by industry begins to replace organization by trade. The structure changes and the specific function of the organization may undergo modification; but the fundamental purposes of organization do not undergo great transformations.

It may therefore safely be asserted that the prime factors in a study of labor organizations, are not: Is the union a trade or an industrial union? Or, is its purpose business or revolutionary? The important questions are: Why has it adopted the ideals, form and methods which are now associated with the organization? And, what are the internal and external, present and past, forces which determine its path to-day? Any classification whether structural or functional is only of value in making clear the factors in the labor problem. A study of social forces is essential in any investigation of labor organizations.

[5] Carlton, "The History and Problems of Organized Labor," p. 108.

THE ENVIRONMENT OF THE APE MAN

BY PROFESSOR EDWARD W. BERRY

JOHNS HOPKINS UNIVERSITY

AT that late epoch of the earth's history which immediately preceded the development of continental ice sheets, or the Pleistocene Glacial period in North America and Europe, we find but little evidence of what the next few thousand of years had in store for the rich terrestrial faunas and floras that had spread from Gibraltar to Korea and probably across the Bering land bridge between Asia and America, and over a part of the latter continent.

The Pliocene age, as the era immediately preceding the Glacial period is termed, probably witnessed the most profuse and diversified mammalian life and arborescent flora that the world has ever seen. The fauna, sometimes known as the Hipparion fauna, from the abundance at that time of the small fleet horses of the Hipparion type, is somewhat better known than the flora for the whole eurasian area, although for the area of Europe the flora is very well represented at a large number of localities. The fauna as shown by the accompanying sketch map (Fig. 1) has been traced from the Tagus Valley on the west to Korea

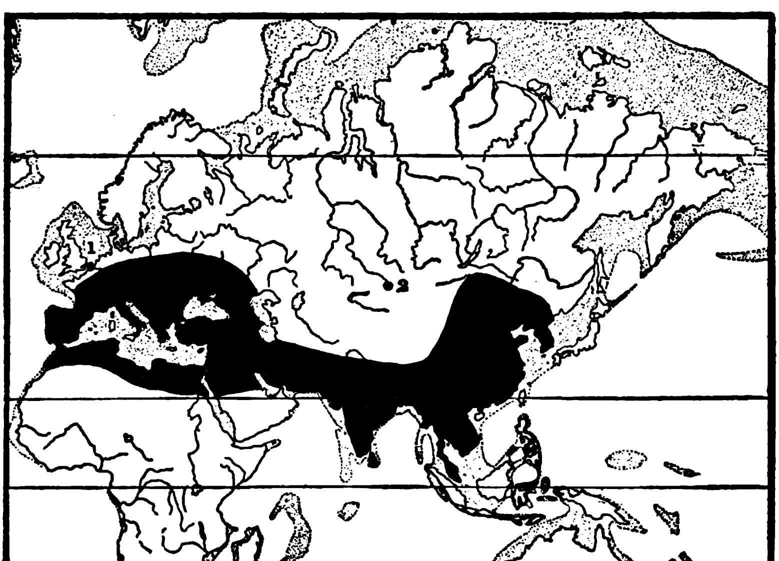

FIG. 1. SKETCH MAP SHOWING RANGE OF THE PLIOCENE HIPPARION FAUNA AND GREATER EXTENSION OF THE FLORA. 1, Pliocene flora of Holland-Prussian border. 2, Pliocene flora of Altai region.

on the east, through 140 degrees of longitude or a distance nearly half way around the world.

The flora has been found at very many localities in Europe associated with this fauna—in Portugal, France, Italy, Germany and throughout the Austrian empire. The less precise work, or possibly the absence of as good material because of the inadequate facilities for preservation in the river floodplain deposits of Asia has hitherto prevented the assembling of data regarding the Pliocene flora of the latter continent. In both Europe and Asia, however, this flora is found beyond the known limits of the fauna. A notable instance is that furnished by the plant remains found in the brick clays of the Holland-Prussian border and recently monographed by Clement Reid[1] and Laurent.[2]

This remarkable flora contains upwards of 300 species and shows a striking similarity to the living flora of the uplands of western China and to its more or less allied geographical provinces, *i. e.,* Japan, the Himalayas, eastern Tibet and the Malay Peninsula. A more remote relationship is shown with the existing flora of Europe or the Caucasus, and a still more remote relationship with the existing flora of North America.

This oriental character, using that term in the sense of its application to existing floral distribution, is shown by the presence in Limburg during the late Pliocene of forms like *Gnetum scandens, Zelkowa keaki, Pyrularia edulis, Magnolia kobus, Prunus maximoviczii, Stewartia pseudo-camellia,* etc., no longer natives of Europe, as well as by representatives of genera such as *Meliosma, Actinidia, Corylopsis, Camptotheca,* etc., not found in the existing European flora but represented by closely allied species in China. Even when the genus is still a member of the European flora, the fossil species appears to be closer to the existing Asiatic rather than the existing European representative, as, for example, in the genera *Pterocarya, Styrax, Betula, Cornus, Clematis, Eupatorium,* etc. There are among the fossils, however, a number of large-seeded forms that are still represented in the flora of Europe, among which may be mentioned *Picea excelsa, Quercus robur, Carpinus betulus, Corylus avellana, Prunus speciosa, Ilex aquifolium, Vitis vinifera* and *Fagus* cf. *silvatica.*

1 Reid, C., and E. M., "Preliminary Note on the Fossil Plants from Reuver, Brunssum and Swalmen," *Tijdsch. Kon. Ned. Aardrijks. Genootschap,* 2e ser., Deel XXVIII., afl. 4, 1911, pp. 645–647; "The Pliocene Floras of the Dutch-Prussian Border," *Mededeelingen Rijksopsporing van Delfstoffen,* No. 6, The Hague, 1915, 178 pp., 4 tf., 20 pls.

2 In Jongmans, W., "Rapport over zijne paleobot," *Rijksopsporing van Defstoffen,* Jahren 1908–11, pp. 23–25; Laurent, L., "Note preliminaire au sujet des plantes pliocenes des argiles du gisement de Reuver et des gisements voisins," Ibidem, Jahren 1914, 4 pp., 1915.

The Reuverian flora, as it has been called, appears to indicate a climate about like that of southern France of the present time, but with a more abundant rainfall. It was richer in species than the present flora of central Europe and the number of arborescent forms was greater, both relatively and absolutely, comprising fifty per cent. of the determined forms. A somewhat similar Pliocene flora was described some years ago from the Altai Mountains[8] in Central Asia. In the latter region were found sequoias, alders, oaks, beeches and tulip trees of North American character associated with oriental beeches, walnuts and maples, as well as with various other trees now characteristic of Mediterranean Europe.

These late Pliocene floras are frequently spoken of as cosmopolitan floras and in the sense that throughout the whole Holarctic region there was not then the geographical differentiation that is displayed by the existing floras this term is true. It does not mean that the semi-arid plains of Algiers had identical species with the forested glades of southern France or that the tropical forests of Indo-China were identical with those of the Asiatic steppes, but there were no well-marked provinces—in Portugal, France, Italy and the Altai we recognize the familiar types like the Sassafras, Magnolia and Tulip tree, which to-day are confined to southeastern Asia or southeastern North America.

This in brief was the setting in which were inaugurated those climatic changes so striking in their results, but probably not nearly so extreme in their actual changes, that resulted in covering so much of Europe and North America with a continental ice sheet many feet in thickness. This was also the setting of that event, great from our human standpoint, when somewhere in the orient the ape-like ancestors of man passed the intangible bound that separated apedom from incipient manhood, for in the older Pleistocene of the island of Java we find the oldest known fossil remains of such an ape man, the *Pithecanthropus erectus* of Dubois, associated with the bones of a large contemporary fauna; and the foliage, fruits and wood of the valley forest in which these remote ancestors of ours dwelt.

The exact age of the strata containing the remains of *Pithecanthropus* is of the greatest importance and on this point as well as on the questions of the environment and climate the fossil flora is much more definite and conclusive than the associated vertebrate and invertebrate fossils. Let us then endeavor to picture the surroundings of the ape man and the animals and plants that spread with him into Java from the river valleys of the Brahmaputra and Irawadi, two thousand miles or more to the northwest, and something of the geography and topography of the lands through which they wandered.

The Pleistocene was in general a time of receding oceans and broad-land connections. Some think that this fall in sea-level was due to the

[8] Schmalhausen, J., "Palæont.," Bd. 33, 1887, pp. 181–216, pl. 18–22.

great amount of water that went into the formation of the ice sheets; at any rate, we know that all the continents were connected, a wide land bridge extended from Asia to North America across Bering sea. In the southeastern Asiatic region the shallow southern half of the China sea, the Gulf of Siam and the shallow Javan sea were all dry land—vast, fertile and well-watered plains teeming with life. Sumatra and Java were connected with Borneo and the Malay peninsula and formed a part of a broad eastward extension of land that reached to and included Timor, the present eastern outpost of the spice islands. These seas are still so shallow that ships can anchor in any part of them.

The Menam River was lengthened a thousand miles and flowed through the Gulf of Siam and sweeping around to the northeast discharged into the China sea. A great Javan river with its headwaters in the vicinity of the straits of Malacca flowed eastward and southward, receiving many large and small tributaries from the uplands of Borneo and Sumatra. It flowed in a broad and densely forested valley extending for a thousand miles along the bed of the Java sea and emptied into the Flores Gulf. The mountain axis of Borneo continued northward nearly or quite connected with Luzon by the enlarged Palawan and Mindoro islands. The Sulu archipelago was a part of western Mindanao and nearly or quite reached north Borneo. The Sangir islands were connected with the northern arm of the Celebes and nearly or quite reached Mindanao while a narrow strait separated Celebes from Borneo, widening north of the former to form the Pleistocene Celebes sea. The Andaman and Nicobar island festoon was connected with lower Burmah forming the large and almost land-locked Gulf of Burmah. The mountain axis of Sumatra was continuous across Java and on to the eastward, for the fault which formed the narrow Sunda Strait between the two islands was not yet in existence. The Pleistocene was also a time of great volcanic activity in this whole region. Java has about 125 volcanic centers many of which are great peaks, but only 13 of these are feebly active at the present time. During the Pleistocene volcanic activity was at a maximum, as is shown by the fact that not only 28 per cent. of the present area of Java consists of these rocks, but most of the remaining area is made up of sediments that are largely volcanic débris. I have endeavored to picture the probable geography of the early Pleistocene in the southeastern Asiatic region in the accompanying sketch map (Fig. 2).

During the early Pleistocene broad and fertile river valleys extended from the Punjab eastward and southward. From the sharp turn in the Brahmaputra at Sadiya in Assam great valleys or verdant coastal plains flanked by salubrious uplands extended southeastward for a distance of between two and three thousand miles and it was along these coastal plains and valleys and the parallel mountain ridges that upland and

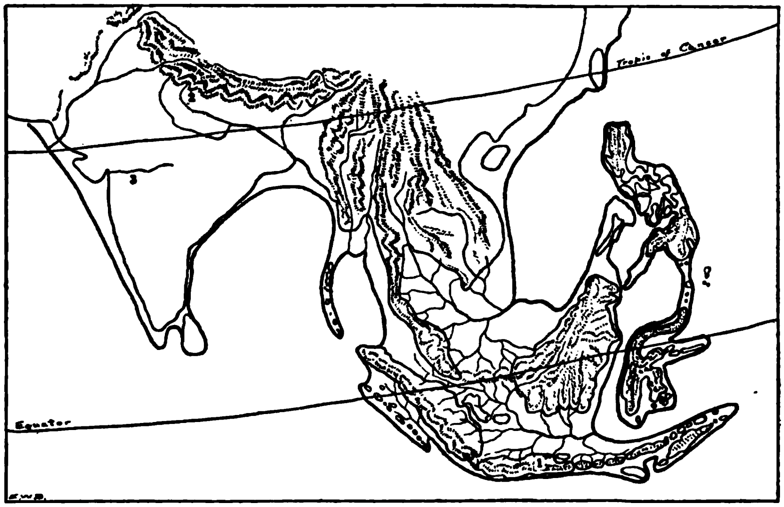

FIG. 2. SKETCH MAP SHOWING PROBABLE LAND CONNECTIONS IN THE SOUTHEASTERN ASIATIC REGION IN THE EARLY PLEISTOCENE. 1, Location of Trinil fossil faunas and floras. 2, Location of Pliocene Siwalik faunas. 3, Location of Pleistocene Narbada faunas.

lowland animals and plants were able to spread simultaneously toward the southeast. The relative elevation of the Himalayan region and a slight lowering of temperature combined with the pressure of population were sufficient to cause this organic flood to gradually spread to the southward.

The *Pithecanthropus* or Trinil men as pictured to us by the anthropologists were of low intelligence, as is indicated by the slight development of the frontal region of the brain, by their cranial capacity of from 850 to 900 cubic centimeters as compared with 600 cubic centimeters for the largest simian brain and 1,200 cubic centimeters for the Neanderthal men of the Third Interglacial period. From a study of the inside of the cranium of the Trinil man it is estimated that the lower frontal lobe, the speech center, was twice as well developed as in any existing anthropoid ape, but still only about half that of Modern man, so it seems certain that the Trinil race possessed at least a rudimentary power of speech.

The remains of the fauna that was contemporaneous with the ape man include fifteen species of land and fresh-water snails and river clams, all of which are still living and in the same general region at the present time. There are several genera of fresh-water fishes; a gavial very close to the existing armored crocodile of the Ganges and a true crocodile close to the existing crocodile of Java and Borneo. Five river and swamp turtles have been described, all similar to living types of farther India and the Sunda islands. Among the birds were parrots

and marabouts. Over a score of mammals, a typical forest and stream border assemblage, have been described. These comprise a macaque, several carnivores including both dogs and cats, two rhinoceroses, a hippopotamus, two wild hogs, several deer including the Sambar deer of India and the Kidang deer still living in Java, buffalo and wild cattle, the porcupine, a large pangolin and hyena, a tapir like the existing Sumatra tapir, and at least three elephants—a *Stegodon* and an *Elephas*, both close to Indian species of the Pliocene (Siwalik) and Pleistocene (Narbada), and another *Elephas* like the straight-tusked *Elephas antiquus* of the early European Pleistocene. This fauna as well as the associated flora are conclusively continental instead of insular in character and were clearly derived from the northwest.[4]

Dubois discovered the remains of *Pithecanthropus* in 1891 along the Bengawan or Solo River near the little hamlet of Trinil in east central Java. To the north are the low east and west range of the Kendeng Hills, to the south lies the high cone of the volcano of Lawoe. His discovery excited the greatest interest and a vast literature has centered around the ape man long thought to be Pliocene in age. During 1907 and 1908 the Selenka expedition made careful excavations at Trinil with the object of supplementing Dubois's scanty material, collecting many vertebrate remains and also the fossil plants which throw such a welcome light on the exact age and environment of the ape man, but failed to find any additionl *Pithecanthropus* remains. The deposits are fluviatile with little regularity in the sequence of bedding and consist of alternating lenticular beds of volcanic débris (lapilli and ashes) sometimes clayey and sometimes sandy, with a total thickness of about 50 feet. The general sequence is as follows:

Recent alluvium.

Kendeng beds:
- Red ashes and lapilli.
- Argillaceous tuff.
- Tufaceous sandstone with a few leaves and bones.
- Tufaceous sandstone with clay balls containing shells.
- Interbedded ash and clay (main plant layer), a few bones.
- Tufaceous sandstone (main bone layer) (*Pithecanthropus*), a few plants and fresh water-shells.

Lahar conglomerate.

The restricted size of the present island of Java, probably of postglacial origin, proved inimical to some of the larger mammals, for the elephant and tapir are absent in the existing fauna, although a rhinoceros still inhabits the uplands. The recentness of Java's separation from the mainland is shown by the Siamese and Indian character of its

[4] Vertebrate paleontologists differ regarding the distinctness of the majority of these animals from those still existing. The majority of the fossils are certainly very close to modern oriental forms.

present fauna and flora. Of its 90 existing mammals no genera and only 5 or 6 species are peculiar. Of its 300 land birds many are Indo-Chinese and only about 45 are peculiar. The modern flora is also distinctly Malayan or Asiatic in character.

The plants found associated with the ape man are of the greatest interest. They number 54 species and the remarkable fact should be noted that none of these are extinct species, a sure indication of their Pleistocene age. Twenty-two families are represented, the most abundant being the bread fruit banyan or fig family (Moraceæ), the custard apple or pawpaw family (Anonaceæ) and the laurel family (Lauraceæ). There were banyans and figs, jack fruit, mangosteen and custard apple, senna and beans, and a variety of other fruit-bearing trees that may have yielded toll to the Trinil race. The Chinese banyan, a large widely spreading, fast-growing tree, a twig of which is shown in the accompanying sketch (Fig. 3), was present at Trinil at that time. The rasamala

FIG. 3. LEAFY FRUIT BEARING SHOOT OF THE CHINESE BANYAN, *Ficus infectoria* Roxb., found fossil at Trinil. 3/7 nat. size.

(*Altingia excelsa* Noronha) related to our sweet gum was also found at Trinil. To-day it does not occur in the vicinity, although it is one of the tallest and noblest trees of central and western Java, extending thence northwestward to the Asiatic mainland.

The present geographical distribution of these early Pleistocene plants is somewhat different from what it was at the time of the ape man and these differences are a measure of the time that has elapsed since those remote days. Only ten of these plants still flourish in the im-

mediate vicinity of Trinil, where the climate is now drier and somewhat warmer, but 32 of them, or 62 per cent., are still found in Java. Twenty-nine, or 57 per cent., are mainly Indo-Chinese and one (*Uvaria*) is now confined to India and Ceylon. The flora was an evergreen forest flora, upland in character, and is much like that found at the present time in the Khassis Mountains of Assam. It indicates the very heavy rainfall of about 150 inches yearly as compared with 60 to 100 inches of the modern records. A mean annual temperature of about 70° is indicated for the early Pleistocene as compared with 75° to 80° of the present.

The heavy rains and slight lowering of temperatures appear to correspond to the times of glaciation in Europe and North America, for it is well known that glaciation in high latitudes was contemporaneous with pluvial periods in the tropics. The survival of so many mammals like those of the Pliocene of the foothills of the Himalayas indicate that the Trinil man lived in early Pleistocene times, but the fact that none of the numerous associated fossil plants are extinct species and that none are identical with known Pliocene plants from Java and Japan indicate that it must have fallen well within the Pleistocene. That the lower bone bed was not appreciably older than the main plant bed which lies over it is shown by the presence of some of the same species of plants and fresh-water shells in the bone bed and by the presence of some of the bones above the main plant bed. We are thus led to the conclusion that *Pithecanthropus* lived in the tropical evergreen forests of Java during the first or second periods of glaciation in Europe and North America, or during what Europeans call the Scanian (Günz) and Saxonian (Mindel) glaciations, corresponding to our Nebraskan and Kansan ice sheets.

This was a long time ago, just how long it is difficult to say. Penck from very careful estimates based on a detailed study of the glaciers of the Alps estimated that the duration of the Pleistocene was between 520,000 and 840,000 years. Osborn considers that *Pithecanthropus* lived about 500,000 years ago. Personally I believe these estimates to be too large. One fact stands out clearly, that very many thousands of years have passed since the ape man and the elephants and hippopotami roamed over Java. Some realization of this time may be gathered if we deal in the more positive ratios rather than in actual estimates of years. If the time that has elapsed since the margin of the ice sheet blocked our great lakes and covered New England be taken as a unit, then the lapse of time since *Pithecanthropus* was buried in the river sands of Java was at least twenty times as great.

When we look at the admirable restoration of *Pithecanthropus* by McGregor we see many indications of the ape ancestry and yet he has managed to catch a look of fleeting intelligence and a dumb prophetic gaze that gives a promise of the great things that the descendants of

this far-off ape man were to accomplish. Whether this early Pleistocene man, by far the oldest yet known, stood in the direct line of ascent to the Neanderthal man which we find later on in Europe, or whether he represented an offshoot of this line, yet one can not contemplate his few bones that have come down to us or that empty brain case without a tremendous thrill.

The earth had been luxuriant and mild for eons, practically all the modern types of animals and plants had already been evolved and then in the dawning days of the Pleistocene with the coming on of more severe climatic conditions we find the early representatives of our own race, subsequently evolving into nomadic hunters and artistic cave dwellers, that spread all over southern Europe, migrating westward in successive waves from the more arid orient. Races that saw the great glaciers of the Rhone and the Rhine and hunted the wild horses and mastodons in southern France. It is a most inspiring history beside which Nineveh and Tyre are as but yesterday.

THE ORIGIN AND EVOLUTION OF LIFE UPON THE EARTH[52]

By HENRY FAIRFIELD OSBORN

COLUMBIA UNIVERSITY; AMERICAN MUSEUM OF NATURAL HISTORY

Lecture I, Part II

Primordial Environment—Energy Derived from the Sun's Heat and Light—Life Elements in the Solar Spectrum

IN the change from the lifeless to the living world the *properties* of the "life elements" become known as *functions*.

The earliest function of living matter appears to have been to capture and transform the electric energy of those chemical elements which throughout we designate as the "life elements." This function appears to have developed only in the presence of heat energy, derived either from the earth or from the sun. This is the first example in the life process of the utilization of energy wherever it may be found. At a later stage of evolution life captured the light energy of the sun through the agency of chlorophyll, the green coloring matter of plants.

If the lifeless surface of the primordial earth was like that of the moon—covered not only with igneous rocks but with piles of heat-storing débris, as recently described by Russell[53]—the reflecting power of the earth's surface represented a loss of 40 per cent. of the sun's heat, as compared with the present reflecting power of the earth which results in a loss of 47 per cent. of the sun's heat; while the solar radiation constant, as measured by Abbott, is 1.923.

The primal dependence of the electric energy of life on the original heat energy of the earth or on solar heat is demonstrated by the universal behavior of the most primitive organisms, because when the temperature of protoplasm is lowered 0° C. the velocity of the chemical reactions becomes so small that in most cases all manifestations of life are suspended, that is, life becomes latent. Some bacteria grow at or very near the freezing point of water (0° C.) and possibly primordial bacteria-like organisms grew below that point. Even now the common "hay bacillus" grows at 6° C.[54] Rising temperatures increase the velocity of the biochemical reactions of protoplasm up to an optimum temperature, beyond which they are increasingly injurious and finally fatal to all organisms. In hot springs some of the Cyanophyceæ (blue-green algæ), primitive plants intermediate in evolution between bacteria

[52] Fourth course of lectures on the William Ellery Hale Foundation, National Academy of Sciences, delivered at the meeting of the academy at Washington, on April 17 and 19, 1916.

[53] Russell, H. N., 1916, p. 75.

[54] Jordan, Edwin O., 1908, pp. 67, 68.

and algæ, sustain temperatures as high as 63° C. and, as a rule, are killed by a temperature of 73° C., which is probably the coagulation point of their proteins. Setchell found bacteria living in water of hot springs at 89° C.[55] In the next higher order of the Chlorophyceæ (green algæ) the temperature fatal to life is lower, being 43° C.[56] Very much higher temperatures are endured by the spores of certain bacilli which survive until temperatures of from 105° C. to 120° C. are reached. There appears to be no known limit to the amount of dry cold which they can withstand.[57]

It is this power of the relatively water-free spores to resist heat and cold which has suggested to Richter (1865), to Kelvin, and to Arrhenius (1908) that living germs may have pervaded space and may have reached our planet either in company with meteorites (Kelvin)[58] or driven by the pressure of light (Arrhenius).[59] The fact that so far as we know life has only originated once and not repeatedly appears to dispose of these hypotheses; nor is it courageous to put off the problem of life origin into cosmic space instead of resolutely seeking it within the forces and elements of our own humble planet.

The thermal conditions of living matter point to the probability that life originated when portions at least of the earth's surface and waters had temperatures of between 89° C. and 6° C.; and also to the possibility of the origin of life before the atmospheric vapors admitted a regular supply of sunlight.

After the sun's heat living matter appears to have captured the sun's light which is essential, directly or indirectly, to all living energy higher than that of the most primitive bacteria. The discovery by Lavoisier (1743–1794) and the development (1804) by de Saussure[60] of the theory of photosynthesis, namely, that sunshine, combining solar heat and light, is a perpetual source of living energy, laid the foundations of biochemistry and opened the way for the establishment of the law of the conservation of energy within the living organism. This was the first conception of the cycle of the elements continually passing through plants and animals which was so grandly formulated by Cuvier in 1817:[61]

[55] *Op. cit.*, p. 68.

[56] Loeb, Jacques, 1906, p. 106.

[57] Cultures of bacteria have even been exposed to the temperature of liquid hydrogen (about —250° C.) without destroying their vitality or sensibly impairing their biologic qualities. This temperature is far below that at which any chemical reaction is known to take place, and is only about 23 degrees above the absolute zero point at which, it is believed, molecular movement ceases. On the other hand, when bacteria are frozen in water during the formation of natural ice the death rate is high. See Jordan, Edwin O., 1908, p. 69.

[58] Poulton, Edward B., 1896, p. 818.

[59] Pirsson, Louis V., and Schuchert, Charles, 1915, pp. 535, 536.

[60] De Saussure, N. T., 1804.

[61] Cuvier, Baron Georges L. C. F. D., 1817, p. 13.

La vie est donc un tourbillon plus ou moins rapide, plus ou moins compliqué, dont la direction est constante, et qui entraîne toujours des molécules de mêmes sortes, mais où les molécules individuelles entrent et d'où elles sortent continuellement, de manière que la *forme* du corps vivant lui est plus essentielle que sa *matière*.

CHEMICAL COMPOSITION OF CHLOROPHYLL

Carbon	73.34
Hydrogen	9.72
Nitrogen	5.68
Oxygen	9.54
Phosphorus	1.38
Magnesium	0.34
	100.00

The green coloring matter of plants is known as chlorophyll; its chemical composition according to Hoppe-Seyler's analysis is given here.[62] Potassium is essential for its assimilating activity. Iron (often accompanied by manganese) although essential to the production of chlorophyll is not contained in it. The chlorophyll-bearing leaves of the plant in the presence of sunlight separate the oxygen atoms from the carbon and hydrogen atoms in the molecules of carbon dioxide (CO_2) and of water (H_2O), storing up the energy of the hydrogen and carbon in the carbohydrate substances of the plant, an energy which is

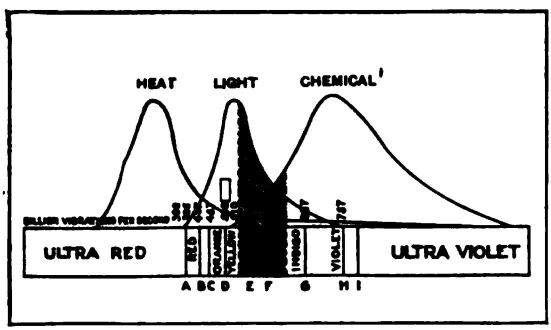

FIG. 1. CURVES SHOWING THE OVERLAPPING OF THE HEAT, LIGHT, AND CHEMICAL WAVES OF THE SUN. After Dahlgren.

stored by deoxidation and which can be released only through reoxidation. Thus the celluloses, sugars, starches, and other similar substances which deposit their kinetic energy in the tissues of the plant, release that energy through the addition of oxygen, the amount of oxygen required being the same as that needed to burn similar substances in the air to the same degree; in brief, a combustion which generates heat.[63] Thus living matter utilizes the energy of the sun to draw a continuous stream of electric energy from the elements in the earth, the water, and the atmosphere.

This was the first step in the interpretation of life processes in the

[62] Sachs, Julius, 1882, p. 758.

[63] W. J. Gies.

terms of physics and chemistry. What was regarded 100 years ago as a special vital force in the life of plants proved to be an adaptation of physico-chemical forces. The chemical action of chlorophyll is not fully understood, but it is known to absorb most vigorously the solar rays between B and C of the spectrum,[64] and these rays are most effective in assimilation. While the effect of the solar rays between D and E is minimal those beyond F are again effective. In heliotropic movements both of plants and animals the blue rays are more effective than the red.[65] Spores given off as ciliated cells from the algæ seek first the blue rays. Since the food supply of animals is primarily derived from chlorophyll-bearing plants animals are less directly dependent on the solar light and solar heat while the chemical life of plants fluctuates throughout the day with the variations of light and temperature. Thus Richards[66] finds in the cacti that the breaking down of the acids through the splitting of the acid compounds is a respiratory process caused by the alternate oxidation and deoxidation of the tissues through the action of the sun.

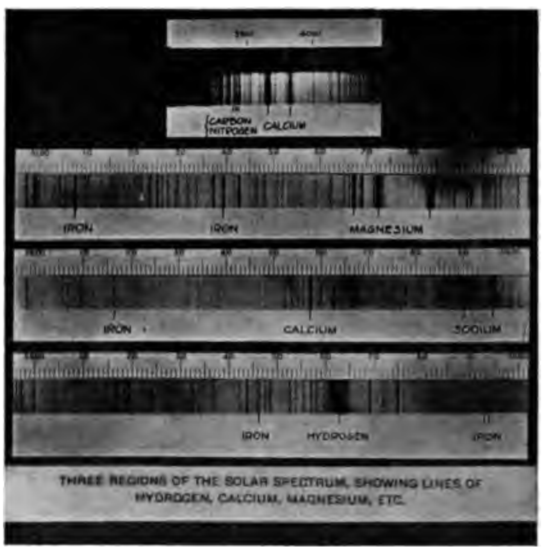

FIG. 2. THREE REGIONS OF THE SOLAR SPECTRUM SHOWING THE LINES OF CARBON, NITROGEN, CALCIUM, IRON, MAGNESIUM, SODIUM AND HYDROGEN. From the the Mt. Wilson Observatory.

The solar energy transformed into the chemical potential energy of the compounds of carbon, hydrogen, and oxygen in the plants is transmuted by the animal into motion and heat and then dissipated. Thus in the life cycle we observe both the conservation and the degradation of

[64] Loeb, Jacques, 1906, p. 115.

[65] *Op. cit.*, p. 127.

[66] Richards, Herbert M., 1915, pp. 34, 73–75.

energy, corresponding with first and second laws of thermodynamics developed in physics by the researches of Newton, Helmholtz, Phillips, Kelvin, and others.[67]

"Life Elements" in the Sun and in our Planet

We have thus observed that the primal earth, air and water contained all the chemical elements and three of the most simple but important chemical compounds, namely, water, nitrates and carbon dioxide, which are known to be essential to the pre-chlorophyllic and chlorophyllic stages of the life process. An initial step in the origin of life was the coordination or bringing together of these elements which, so far as we know, had never been in combined action before and are widely distributed as they appear in the solar spectrum. Therefore, before examining the properties of these elements further, it is interesting to trace them back into the sun and thus into the cosmos.

Excepting hydrogen and oxygen, the principal elements which enter into the formation of protoplasm are minor constituents of the mass of matter sown throughout space in comparison with the rock-forming elements.[68] Again excepting hydrogen, their lines in the solar spectrum are for the most part weak and only shown on high dispersion plates, while hydrogen is represented by very strong lines as shown by spectroheliograms of solar prominences. The lines of oxygen are relatively faint; it appears principally as a compound, titanium oxide (TiO_2), in sunspots although a triple line in the extreme red seems also to be due to it. In the chromosphere, or higher atmosphere of the sun, hydrogen is not in a state of combustion, and the fine hydrogen prominences show radiations comparable to those in a vacuum tube.[69]

Nitrogen, the next most important life element, is displayed in the so-called cyanogen bands of the ultra-violet, made visible by high dispersion photographs. Carbon is shown in many lines in green, which are relatively bright near the sun's edge; it is also present in comets, and carbonaceous meteorites (Orgueil, Kold Bokkeveld, etc.) are well known. Graphite occurs in meteoric irons.

In the solar spectrum so far as studied no lines of the "life elements," phosphorus, sulphur, and chlorine, have been detected. On the other hand, the metallic elements which enter into the life compounds, iron, sodium and calcium, are all represented by strong lines in the solar spectrum, the exception being potassium in which the lines are faint. Of the eight metallic elements which are most abundant in the earth's crust as well as the non-metallic elements carbon and silicon, six are also among the eight strongest in the solar spectrum. In general, however, the important life elements are very widely distributed

67 Henderson, Lawrence J., 1913, pp. 15–18.

68 Russell, Henry Norris, letter of March 6, 1916.

69 Hale, George Ellery, letter of March 10, 1916.

in the stellar universe, showing most prominently in the hotter stars, and in the case of hydrogen being universal.

Action and Reaction as Adaptive Properties of the Life Elements

Of the total of eighty-two or more chemical elements thus far discovered at least twenty-nine are known to occur in living organisms either invariably, frequently, or rarely, as shown in the accompanying Table II of the Life Elements. The adaptation of the life elements is due to their incessant action and reaction, each element having its peculiar and distinctive forms of action and reaction, which in the organism are transmuted into functions. Such activity of the life elements is largely connected with forms of electric energy which the physicists call *ionization,* while the correlated or coordinated *interaction* of various groups of life elements is largely connected with processes which the chemists term *catalysis.* Of catalysis we shall speak later.

Ionization, the actions and reactions of all the elements and electrolytic compounds—according to the hypothesis of Arrhenius, first put forth in 1887—is primarily due to electrolytic dissociation whereby the molecules of all acids (*e. g.,* carbonic acid, H_2CO_3), bases (*e. g.,* sodium hydroxide, NaOH), and salts (*e. g.,* sodium chloride, NaCl) give off streams of the electrically charged particles known as ions. Ionization is dependent on the law of Nernst that the greater the dielectric capacity of the solvent (*e. g.,* water) the more rapid will be the dissociation of the substances dissolved in it; other conditions remaining the same. Thus ions are atoms or groups of atoms carrying electric charges which are positive when given off from metallic elements, and negative when given off from non-metallic elements. Electrolytic molecules, according to this theory, are constantly dissociating to form ions and the ions are as constantly recombining to form molecules. Since the salts of the various mineral elements are constantly being decomposed through electrolytic ionization, they play an important part in all the life phenomena; and since similar decomposition is induced by currents of electricity, indications are that all the development of living energy is in a sense electric.

In Rutherford's experiments on radioactive matter[70] he tells us that in the phosphorescence caused by the approach of an emanation of radium to zinc sulphate the atoms throw off the alpha particles to the number of five billion each second with velocities of 10,000 miles a second; that the alpha particles in their passage through air or other medium produce from the neutral molecules a large number of negatively charged ions, and that this ionization is readily measurable.

Phosphorescence in plants and animals is also regarded by Loeb[71] as

[70] Rutherford, Sir Ernest, 1915, p. 115.

[71] Loeb, Jacques, 1906, pp. 66–68.

a form of radiant energy. While developed in a number of living animals—including the typical glowworms in which the phenomenon was first investigated by Faraday—the living condition is not essential to it because the phosphorescence continues after death and may be produced in animals by non-living material. Many organisms show phosphorescence at comparatively low temperatures, yet the presence of free oxygen appears to be necessary.

Finally, we observe that ionization is connected with the radioactive elements, of which thus far only radium has been detected in the organic compounds although the others may be present.

The ionizing electric properties of the life elements are a matter of first importance. We observe at once in the table below that all the great structural elements which make up the bulk of plant and animal tissues are of the non-metallic group with negative ions, with the single exception of hydrogen which has positive ions. All these elements are of low atomic weight and several of them develop a great amount of heat in combustion, hydrogen and carbon leading in this function of the

TABLE II

THE LIFE ELEMENTS, SHOWING THEIR PRINCIPAL PROPERTIES AND FUNCTIONS IN PLANTS AND ANIMALS

Mainly or Wholly with or in Negative Ions[72]		Mainly or Wholly with or in Positive Ions[72]		
Non-metallic		Metallic		
[73] **Carbon** (*e. g.*,[75] carbonates)	**Silicon**	[77] **Hydrogen**	[78] **Iron**	**Lithium**
[73] **Oxygen** (*e. g.*,[75] sulphates)	**Iodine**	**Potassium**	**Copper**	**Nickel**
[73] [74] **Nitrogen** (*e. g.*,[75] nitrates)	**Bromine**	**Sodium**	**Aluminum**	**Radium**
[73] **Phosphorus** (*e. g.*,[75] phosphates)	**Fluorine**	**Calcium**	**Barium**	**Strontium**
[73] **Sulphur** (*e. g.*,[75] sulphates)	**Boron**	**Magnesium**	**Cobalt**	**Zinc**
Chlorine	[76] **Arsenic**	**Manganese**	**Lead**	

Ionization Elements thus far Discovered in Living Organisms

72 An ion is an atom or group of atoms carrying an electric charge. The positive ions (cations) of the metallic elements move toward the cathode: the negative ions (anions) given off by the non-metallic elements move toward the anode.

73 Together with hydrogen conspicuous in living colloids and non-electrolytes —very little in the indicated ionized forms.

74 Occurs also, as NH_4, in *positive* ions. Here the hydrogen overbalances the nitrogen.

75 Substances occurring in living matter.

76 Arsenic itself is a metal, but in living compounds it is an analogue of phosphorus and occurs in *negative* ions when ionized.

77 Pictet has obtained results indicating that liquid and solid hydrogen are metallic. Hydrogen is metallic in *behavior,* though non-metallic in *appearance.*

78 Iron in living compounds is chiefly non-ionized, colloidal. Apparently this is also true of copper, aluminum, barium, cobalt, lead, nickel, strontium and zinc. As to radium, however, there is no information on this point.

Elements Invariably Present in Living Organisms[79]

Atomic Weight	Heat Combustion per Gram	Element	Symbol	Plants	Animals
1.008	34.702 cal. (H_2)	*Hydrogen*	H	Hydrogen, carbon, oxygen, and nitrogen—"C, O, H,	N"—are *essential and of chief rank* in all life proc-
12.005	8.08 "	*Carbon*	C	esses; forming, with sulphur, practically all plant	and animal proteins, and, with phosphorus, form-
16.00		*Oxygen*	O	ing the nucleoproteins.	
14.01	0.143 "	*Nitrogen*	N		
31.04	5.747 "	*Phosphorus*	P	In nucleoproteins and phospholipins.	In nucleoproteins and phospholipins; in some brachiopods; in blood; and in vertebrate bone and teeth.
32.06	2.22 "	*Sulphur*	S	In most proteins, 0.1–5.0 per cent.	In most proteins, 0.1–5.0 per cent.
39.16	1.745 "	*Potassium*	K	Abundant in marine plants, esp. "kelps" (larger *Phæophyceæ*); activity of chlorophyll depends on it.	In blood, muscle, etc.
24.32	6.077 "	*Magnesium*	Mg	Present in large quantities in *Corallinaceæ* (a family of calcified red algæ).	Present in echinoderms and alcyonarians;[80] present in all parts of vertebrates, esp. in bones.
40.07	3.284 "	*Calcium*	Ca	Present in large quantities in certain algæ (chiefly marine).	In all parts of vertebrates; abundant in bones and teeth
55.84	1.353 "	*Iron*	Fe	Essential in the formation of protoplasm.	Essential in the formation of protoplasm, and in the higher animals; essential in hemoglobin as an oxygen carrier.
23.00	3.293 "	?*Sodium*	Na	Believed essential to all plants, but not demonstrated; found in marine plants, esp. *Phæophyceæ*.	Present in all animals; abundant in blood and lymph.
35.46	0.254 "	?*Chlorine*	Cl	Present in many plants; believed by some to be essential; abundant in marine algæ, esp. in the *Phæophyceæ*.	Present in all animals; abundant in blood and lymph; present in the gastric juice.
28.3		?*Silicon*	Si	Found in all plants; present in large quantities in the *Diatomaceæ*, both fresh-water and marine; in form of "silica" constitutes 0.5–7.0 per cent. of the ash of ordinary marine algæ.	Present in radiolarians and siliceous sponges; also in all the higher animals.

[79] Observe that the most active elements in organic compounds generally have low atomic weights; and that the most active element, hydrogen, has the highest combustion heat in calories per gram.

[80] Magnesium is also found in many other invertebrates than those mentioned.

Elements Frequently Present in Living Organisms

Atomic Weight	Heat Combustion per Gram	Element	Symbol	Plants	Animals
126.92	0.1766 cal.	*Iodine*	I	In marine plants, esp. the "brown algæ," *Phæophyceæ;* in *Laminaria* and *Fucus;* also in some Gorgonias.	Essential in the higher animals (thyroid).
54.93		*Manganese*	Mn	In some plants.	In most animals in very slight proportions.
79.92		*Bromine*	Br	In marine plants, esp. the "brown algæ," *Phæophyceæ;* in some Gorgonias.	In some animals in very slight proportions.
19.0		*Fluorine*	F	In a few plants.	In some animals—constituent of bones and teeth; in shells of molluscs and in vertebrate bones.

Elements Rarely Present in Living Organisms

Atomic Weight	Heat Combustion per Gram	Element	Symbol	Plants	Animals
27.1		[81]*Aluminum*	Al	In a few plants.	In a few animals.
74.96	1.463 cal.	[81]*Arsenic*	As		In some animals.
137.37	0.952 "	[81]*Barium*	Ba	In a few plants.	
11.0		*Boron*	B	In some plants.	
58.97		[81]*Cobalt*	Co	In a few plants.	
63.57	0.585 "	[81]*Copper*	Cu	In a few plants.	Traces in some corals; essential in some lower animals as oxygen carrier.
207.20	0.243 "	[81]*Lead*	Pb		Traces in some corals.
6.94		*Lithium*	Li	In some plants.	
58.08		[81]*Nickel*	Ni	In a few plants.	
226.0		[81]*Radium*	Ra	In some plants.	In some animals.
87.63	1.497 "	[81]*Strontium*	Sr	In a few plants.	
65.37	1.291 "	[81]*Zinc*	Zn	In a few plants.	In a few animals; traces in some corals.

The exceedingly rare occurrence of cerium, chromium, didymium, lanthanum, molybdenum, silver and vanadium is in all probability merely adventitious.

[81] Commonly regarded as poisons when present in *mineral* (ionic) forms, even in small proportions.

release of energy, which invariably takes place in the presence of oxygen. On the other hand, the lesser components of organic compounds are the metallic elements with positive ions, such as potassium, sodium, calcium, and magnesium, calcium combining with carbon or with phosphorus as the great structural or skeletal builder in animals. There is also so much carbonaceous protein in the animal skeleton that in animals calcium takes the place of carbon in plants only in the sense that it reduces the *proportion* of carbon in the skeleton: it shares the honors with carbon.

In general the electric action and reaction of the non-metallic and the metallic elements dissolved or suspended in water is believed to be the source of all the internal functions of life, which are developed always in the presence of oxygen and with the energy either of the heat of the earth, or of the sun, or of both the heat and light of the sun.

Cosmic Properties and Life Functions of the Chief Life Elements

Both the time and the mode of the origin of life is a matter of pure speculation, in which we have as yet no observation or uniformitarian reasoning to guide us, for all the experiments of Bütschli and others to imitate the original life process have proved fruitless. We may, however, put forward four hypotheses in regard to it, as follows:

First: we may advance the hypothesis that an early step in the organization of living matter was the assemblage one by one of several of the ten elements essential to life, namely, hydrogen, oxygen, nitrogen, phosphorus, sulphur, potassium, calcium, magnesium, iron (also perhaps silicon), and carbon, which are present in all living organisms with the exception of some of the most primitive forms of bacteria, which may lack carbon, magnesium, iron and silica. Of these the four most important elements were obtained from their previous combination in water (H_2O), from the nitrogen compounds of volcanic emanations or from the atmosphere,[82] consisting largely of nitrogen and from atmospheric carbon dioxide (CO_2). The remaining six elements, phosphorus, sulphur, potassium, calcium, magnesium and iron, came from the earth.

Second: whether there was a sudden or a more or less serial grouping of these elements, one by one, we are led to a second hypothesis that they were gradually bound by a new form of mutual attraction whereby the actions and reactions of a group of life elements established a new form of unity in the cosmos, an organic unity or *organism* quite distinct from the larger and smaller aggregations of inorganic matter previously held or brought together by the forces of gravity. Some such stage of

[82] Ammonia is also formed by electrical action in the atmosphere and unites with the nitric oxides to form ammonium nitrate or nitrite: these compounds fall to earth in rain.—F. W. Clarke.

mutual attraction may have been ancestral to the cell, the primordial unity and individuality of which we shall describe later.

Third: this leads to the hypothesis that this grouping occurred in the gelatinous state described as "colloidal" by Graham.[83] Since all living cells are colloidal it appears probable that this grouping of the "life elements" took place in a state of colloidal suspension, for it is in this state that the life elements best display their incessant action, reaction and interaction. Bechhold[84] observes that

> Whatever the arrangement of matter in living organisms in other worlds may be, it must be of colloidal nature. What other condition except the colloidal could develop such changeable and plastic forms, and yet be able, if necessary, to preserve these forms unaltered?

Fourth: with this assemblage, mutual attraction, and colloidal condition, a fourth hypothesis is that there arose the rudiments of competition and selection. Was there any stage in this grouping, assemblage, and organization of life forms, however remote or rudimentary, when the law of natural selection did not operate between different unit aggregations of matter? Probably not, because *each of the chemical life elements possesses its peculiar properties which in living compounds best serve certain functions.* This cooperation was also an application of energy new to the cosmos. In other words, every element, as shown

FIG. 3. TWO PHOTOGRAPHS OF THE SUN SHOWING (LEFT) THE CLOUDS OF CALCIUM VAPOR IN THE SOLAR ATMOSPHERE, AND (RIGHT) GROUPS OF SUN SPOTS. From the Mt. Wilson Observatory.

in Table II., "The Life Elements" (pp. 176–178), and in the descriptions below, has its single or multiple services to render to the organism.

Hydrogen, the life element of least atomic weight, is always near the surface of the typical hot stars. Rutherford[85] tells us that while the hydrogen atom is the lightest known its negatively charged electrons

[83] Over fifty years ago Thomas Graham introduced the term "colloid" (L. *colla,* glue) to denote coagulating substances like gelatine, a typical colloid, as distinguished from crystalloids. Proteins belong to that class of colloids which, once coagulated, can not return to the liquid condition.

[84] Bechhold, Heinrich, 1912, p. 194.

[85] Rutherford, Sir Ernest, 1915, p. 113.

are only about 1/1800 of the mass of the hydrogen atom: they are liberated from metals on which ultra-violet light falls, and can be released from atoms of matter by a variety of agencies. Hydrogen is present in all acids and in most organic compounds. It also has the highest power of combustion.[86] Its ions are very important factors in animal respiration and in gastric digestion.[87] It is very active in dissociating or separating oxygen from various compounds, and through its affinity for oxygen forms water (H_2O), the principal constituent of protoplasm.

Oxygen, like hydrogen, has an attractive power which brings into the organism other elements useful in its various functions. It makes up two thirds of all animal tissue as it makes up one half of the earth's crust. Beside these attractive and synthetic functions its great service is as an oxidizer in the release of energy; it is thus always circulating in the tissues. Through this it is involved in all heat production and in all mechanical work, and affects cell division and growth.[88]

Nitrogen comes next in importance to hydrogen and oxygen as structural material[89] and when combined with carbon and sulphur gives the plant and animal world one of the chief organic food constituents, protein. It was present on the primordial earth, not only in the atmosphere but also in the gases and waters emitted by volcanoes. Combined with hydrogen it forms various radicles of a basic character (*e. g.,* NH_2 in amino acids, NH_4 in ammonium compounds); combined with oxygen it yields acidic radicles such as NO_3 in nitrates. It combines with carbon in $-C\equiv N$ radicles and in $\equiv C-NH_2$ and $=C=NH$ forms, the latter being particularly important in protoplasmic chemistry.[90] This life element forms the basis of all explosives, it also confers the necessary instability upon the molecules of protoplasm because it is loath to combine with and easy to dissociate from most other elements. Thus we find nitrogen playing an important part in the physiology of the most primitive organisms known, the nitrifying bacteria.

Carbon also exists at or near the surface of cooling stars which are becoming red.[91] It unites vigorously with oxygen, tearing it away from neighboring elements, while its tendency to unite with hydrogen is less marked. At lower heats the carbon compounds are remarkably stable, but they are by no means able to resist great heats; thus Barrell[92] observes that a chemist would immediately put his finger on the element carbon as that which is needed to endow organic substance with complexity of form and function, and its selection in the origin of plant life

86 Henderson, Lawrence J., 1913, pp. 218, 239, 245.

87 Gies, W. J.

88 Loeb, Jacques, 1906, p. 16.

89 Henderson, Lawrence J., 1913, p. 241.

90 Gies, W. J.

91 Henderson, Lawrence J., 1913, p. 55.

92 Barrell, Joseph, letter of March 20, 1916.

was by no means fortuitous. Including the artificial products the known carbon compounds exceed 100,000, while there are thousands of compounds of C, H, and O, and hundreds of C and H.[93] Carbon is so dominant in living matter that biochemistry is very largely the chemistry of carbon compounds; and it is interesting to observe that in the evolution of life each of these biological compounds must have arisen suddenly as a saltation or mutation, there being no continuity between one chemical compound and another.

FIG. 4. (LOWER) SOLAR PROMINENCES SURROUNDING THE SUN. (UPPER) THE SAME GREATLY ENLARGED. From Mt. Wilson Observatory.

Phosphorus is essential in the nucleus of the cell,[94] being a large constituent of the intranuclear germ plasm, or chromatin, which is the seat of heredity. It enters largely into the structure of nerves and brain, and also, as phosphates of calcium and magnesium, serves an entirely diverse function as building material for the skeletons of animals.

Sulphur, uniting with nitrogen, oxygen, hydrogen and carbon, is an essential constituent of the proteins of plants and animals.[95] It is especially conspicuous in the epidermal protein known as keratin, which by its insolubility mechanically protects the underlying tissues.[96] Sulphur

[93] Henderson, Lawrence J., 1913, p. 193.

[94] *Op. cit.*, p. 241.

[95] *Op. cit.*, p. 242.

[96] Pirsson, Louis V., and Schuchert, Charles, 1915, p. 434.

is also contained in one of the physiologically important substances of bile.[97]

Potassium separates hydrogen from its union with oxygen in water, and is the most active of the metals, biologically considered, in its positive ionization.[98] Through stimulation and inhibition potassium salts play an important part in the regulation of life phenomena, and they are essential to the living tissues of plants and animals, fresh-water and

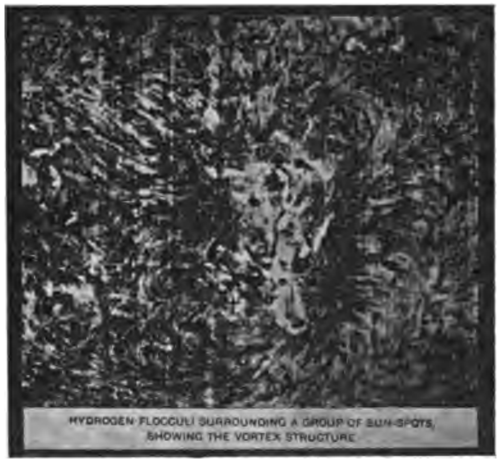

FIG. 5. HYDROGEN FLOCCULI SURROUNDING A GROUP OF SUN SPOTS SHOWING THE VORTEX STRUCTURE. From the Mt. Wilson Observatory.

marine plants, in particular, storing up large quantities in their tissues.[99] Potassium is of service to life in building up complex compounds from which the potassium can not be dissociated as a free ion; it is thus one of the building stones of living matter.[100]

Magnesium is fourth in order of activity among the metallic elements. It is essential to the chlorophyll, or green coloring matter of plants, which in the presence of sunshine serves in the dissociation of oxygen from the carbon of carbon dioxide and the hydrogen of water. It is also found in the skeletons of many invertebrates and in the coralline algæ.

Calcium is third in order of activity among the metallic elements. According to Loeb[101] it plays an important part in the life phenomena through stimulation (irritability) and inhibition. It unites with carbon as carbonate of lime and is contained in many of those animal skeletons which, through deposition, make up an important part of the earth's crust. In invertebrates the carbonate, except in certain brachiopods, is

97 Gies, W. J.

98 Caesium is more electropositive.—F. W. Clarke.

99 Loeb, Jacques, 1906, p. 94.

100 *Op. cit.*, p. 72.

101 *Op. cit.*, 1906, p. 94.

far more important as skeletal material than the phosphates: the limestones form only about five per cent. of the sedimentaries. Shales and sandstones are far more abundant.

Iron is essential for the production of chlorophyll[102] though, unlike magnesium, it is not contained in it. It is present as well in all protoplasm, while in the higher animals it serves, in the form of oxyhemoglobin, as a carrier of oxygen from the lungs to the tissues.[103]

Sodium is less important in the nutrition of plant tissues, but serves an essential function in all animal life in relation to movement through muscular contraction.[104] Its salts, like those of calcium, play an important part in the regulation of life phenomena through stimulation and inhibition.[105]

Iodine, with its negative ionization, becomes useful through its capacity to unite with hydrogen in the functioning of the brown algæ and in many other marine organisms. It is also an organic constituent in the thyroid gland of the vertebrates.[106] The iodine content of crinoids—stalked echinoderms—varies widely in organisms gathered from different parts of the ocean according to the temperature and the iodine content of the sea-water. Iodine and bromine are important constituents of the organic axes of gorgonias.

Chlorine, like iodine, a non-metallic element with negative ions, is abundant in marine algæ and present in many other plants, while in animals it is present in both blood and lymph. In union with hydrogen as hydrochloric acid it serves a very important function in the gastric digestion of proteins.[107]

Barium, rarely present in plants, has been used in animal experimentation by Loeb, who has shown that its salts induce muscular peristalsis and accelerate the secretory action of the kidneys.[108]

Copper ranks first in electric conductivity. In the invertebrates, in the form of hemocyanine, it acts as an oxygen carrier in the fluid circulation to the tissues.[109] It is always present in certain molluscs, such as the oyster, and also in the plumage of a bird, the Turaco. Although among the rare life elements it ranks first in toxic action upon fungi, algæ, and in general upon all plants, yet it is occasionally found in the tissues of trees growing in copper-ore regions.[110]

In general most of the metallic compounds and several of the nonmetallic compounds are toxic or destructive to life when present in large

102 Sachs, Julius, 1882, p. 699.
103 Henderson, Lawrence J., 1913, p. 241.
104 Loeb, Jacques, 1906, p. 79.
105 *Op. cit.*, pp. 94, 95.
106 Henderson, Lawrence J., 1913, p. 242.
107 *Op. cit.*, p. 242.
108 Loeb, Jacques, 1906, p. 93.
109 Henderson, Lawrence J., 1913, p. 241.
110 Howe, M. A., letter of February 24, 1916.

quantities. All the mineral elements of high atomic weight are toxic in comparatively minute proportions, while the essential life elements of low atomic weight are toxic only in comparatively large proportions. Toxicity depends largely upon the liberation of ions, and non-ionized and non-ionizable organic compounds—such as hemoglobin containing non-ionizable iron—are wholly non-toxic.

We thus return to the conception set forth above in our four hypotheses that in the origin and early evolution of the life-organism the gradual selection and grouping of the ten chief life elements and of the nineteen or more subsequently added may have been analogous to a series of inventions and discoveries or to the successive addition of new characters and functions such as we may trace through paleontology in the origin and development of the higher plants and animals.

Prior to the entrance into the organism of the active metals there may have arisen the utilization of the binary compounds of carbon and oxygen (CO_2) and of hydrogen and oxygen (H_2O), to the attractive power of which Henderson[111] has especially drawn our attention. He points out that it is the attraction of oxygen or of hydrogen or of both combined which is now bringing and in the past may have brought into the organism other elements useful to it in its various functions. In other words, oxygen and hydrogen were *selective* agents. In fact, those inorganic compounds which contain neither hydrogen, carbon, nor oxygen make up but a very small percentage of the substance of known bodies. Further, the most active inorganic compounds contain either hydrogen or oxygen. All acids contain hydrogen, most of them oxygen as well, and many bases contain oxygen, although such bases as ammonium (NH_4) do not. Thus hydrogen and oxygen are elements unrivaled in chemical activity, which enable living organisms to make use of other elements at need.

The incorporation of the active metals, potassium, sodium, calcium, magnesium, iron, manganese and copper, into the substance of living organisms may have occurred in the order of their activity in capturing energy from the environment and storing it within the organism. For example, an immense period of time may have been traversed before there occurred the addition of magnesium and iron to certain hydrocarbons which enabled the plant to draw upon the energy of solar light.

Adaptation in the Colloidal State

In the lifeless world matter occurred both in the crystalloidal and colloidal states. It is in the latter state, as observed above (p. 180), that life originated. It is a state peculiarly favorable to action, reaction, and interaction, or the free interchange of physico-chemical energies. Each organism is in a sense a container full of a watery solution in which

111 Henderson, Lawrence J., 1913, pp. 239, 240.

various kinds of colloids are suspended.[112] Such a suspension involves a play of the energies of the free particles of matter in the most delicate equilibrium, and the suspended particles exhibit the vibrating movement attributed to the impact of the molecules.[113] These free particles are of greater magnitude than the individual molecules, in fact, they represent molecules and multimolecules; and all the known properties of the compounds known as "colloids" can be traced to feeble molecular affinities between the molecules themselves, causing them to unite and to separate in multimolecules. Among the existing living colloids are certain carbohydrates, like starch or glycogen, proteins (compounds of carbon, hydrogen, oxygen and nitrogen with sulphur or phosphorus), and the higher fats. The colloids of protoplasm are dependent for their stability on the constancy of acidity and alkalinity, which is more or less regulated by the presence of bicarbonates.[114]

Electrical charges in the colloids[115] are demonstrated by currents of electricity sent through a colloidal solution, and are interpreted by Freundlich as due to electrolytic dissociation of the colloidal particles, alkaline colloids being positively charged while acid colloids are negatively charged. The concentration of hydrogen and hydroxyl ions in the ocean and in the organism is automatically regulated by carbonic acid (CO_2).[116]

Among the colloidal substances in living organisms the so-called enzymes are very important since they are responsible for many of the processes in the organism. Possibly enzymes are not typical colloids and perhaps, in pure form, they may not be classified as such; but if they are not colloids they certainly behave like colloids.[117]

Coordination of the Properties of the Life Elements through Interaction

We have thus far traced the actions and reactions of the life elements, which are mainly contemporaneous, direct, and immediate; they do not suffice to form an organism. As soon as the grouping of chemical elements reaches the stage of an organism interaction becomes essential, for the chemical activities of one region of the organism must be harmonized with those of all other regions; the principle of interaction may apply at a distance and the results may not be contemporaneous. This is actually inferred to be the case in single-celled organisms such as the *Amœba*.[118]

The interacting and coordinating form of lifeless energy which has

112 Bechhold, Heinrich, 1912.
113 Smith, Alexander, 1914, p. 305.
114 Henderson, Lawrence J., 1913, pp. 157–160.
115 Loeb, Jacques, 1906, pp. 34, 35.
116 Henderson, Lawrence J., 1913, p. 257.
117 Hedin, Sven G., 1914, pp. 164, 173.
118 Calkins, Gary N., 1916, pp. 259, 260.

proved to be of the utmost importance in the life processes in that recognized in the early part of the nineteenth century and denoted by the term catalysis, first applied by Berzelius in 1835. A catalyzer is a substance which modifies the velocity of a distant chemical reaction without itself being used up by the reaction. Thus chemical reactions may be accelerated or retarded and yet the catalyzer loses none of its energy. In a few cases it has been definitely ascertained that the catalytic agent does itself experience a series of changes. The theory is that catalytic phenomena depend upon the alternate decomposition and recomposition, or the alternate attachment and detachment of the catalytic agent.

Discovered as a property in the inorganic world catalysis has proved to underlie the great series of functions in the organic world which may be comprised in the physical term *interaction*. The researches of Ehrlich and others fully justify Huxley's prediction of 1881 that through therapeutics it would become possible "to introduce into the economy a molecular mechanism which, like a cunningly contrived torpedo, shall find its way to some particular group of living elements and cause an explosion among them, leaving the rest untouched." In fact, the interacting agents known as "enzymes" are such living catalyzers[119] which accelerate or retard reactions in the body by forming intermediary unstable compounds which are rapidly decomposed, leaving the catalyzer (*i. e.,* enzyme) free to repeat the action. Thus a small quantity of an enzyme can decompose indefinite quantities of a compound. The activity of enzymes is rather in the nature of the "interaction" of Newton than of direct action and reaction, because the results are produced at a distance and the energy liberated may be entirely out of proportion to the internal energy of the catalyzer. The enzymes being themselves complex organic compounds act specifically because they do not affect alike the different organic compounds which they encounter in the fluid circulation.

Hence, as a fifth hypothesis relating to the origin of organisms, we may advance the idea that the evolution and specialization of various catalyzers (including enzymes or "unformed ferments") has proceeded step by step with the evolution of plant and animal functions. In the evolution from the single-celled to the many-celled forms of life and the multiplication of these cells into hundreds of millions, into billions, and into trillions, as in the larger plants and animals, biochemical coordination and correlation become increasingly essential. In fact, none of the discoveries we have hitherto described throws greater illumination on the life processes than this connected with the internal secretions and the by-products of metabolism in the circulation of the plant and animal fluids. It is known that, as Huxley prophesied, enzymes do reach particular groups of living elements and leave others untouched. For example, the enzyme developed in the yeast ferment produces a different

[119] Loeb, Jacques, 1906, pp. 26, 28.

result in each one of a series of closely related carbohydrates.[120] Driesch[121] has suggested that within the nucleus of the cell is a storehouse of these ferments which pass out into the protoplasm tissues and there set up specific activities; and recently it has been suggested that it is hormones which affect certain hereditary determiners in the chromatin or germ plasm itself.

In 1849 there was given the first experimental proof of action exercised upon an organism by a ductless gland.[124] Berthold transplanted the testicles of young cocks, which afterward developed the masculine voice, sexual desire, comb, and love of combat, thus anticipating Brown-Sequard, who committed himself to the view that a gland, ductless or not, elaborated substances essential to the growth and maintenance of the body. Continuing the investigation of the *chemical correlation of the activities of animal bodies,* Bayliss and Starling proposed the name "hormones" (ὁρμάω, to awaken, stir up). Hormone-producing agents develop from certain *endocrine* organs or glands of internal secretion. The secretion of a gland may act indirectly: *e. g.,* the influence of the thyroid by way of the thymus upon the activities of the stomach.

The heredity theory proposed by Cunningham[122] was based upon the discovery that the connection between the germ cells and the secondary sexual organs, which was supposed to be of a nervous nature, is really chemical. Since hormones from the germ cells determine the development of many other bodily organs, it is possible that hormones due to various cellular activities in the body may act upon the determiners in the germ cells which correspond to the tissues from which these hormones are derived. Cunningham's hypothesis suggests a means by which bodily modifications due to environmental and developmental conditions could modify corresponding determiners in the germ cells.

Catalytic action originates in the by-products of single chemical combinations. For example, the carbon dioxide liberated in cell metabolism acts at a distance on other portions of the cell and of the organism. "In a sense, too," observes Abel, "as has been frequently pointed out, every cell of the body furnishes in the carbon dioxide which it eliminates a hormone or product of internal secretion, since under normal conditions the carbon dioxide of the blood is one of the chief regulators of the respiratory center, influencing this center by virtue of its acidic properties."[123] But in the course of evolution certain entire cells and finally groups of cells took on this function of coordinating and correlating the activity of the complex organism. Thus certain glands arose.

Among the catalysers are those which accelerate general growth through stimulating specific chemical activities and others which retard

120 Moore, F. J., 1915, p. 170; and Loeb, Jacques, 1906, pp. 21, 22.

121 Wilson, Edmund B., 1906, p. 427.

122 Cunningham, J. T., 1908, pp. 372–428.

123 Abel, John J., 1915, p. 168.

124 Halsted, William Stewart, 1914, pp. 224, 225.

general growth. There are also catalysers which accelerate or retard the growth of certain organs or parts of the body. The enzyme theory has developed with extreme rapidity but is still, doubtless, in its infancy.

In the concluding section of this lecture we shall trace these physical and chemical principles into some of the simpler forms of life.[126]

(To be continued)

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[126] In addition to the acknowledgments made in the introduction, I especially desire to express my indebtedness to Henry Norris Russell, of Princeton University, to George Ellery Hale, of the Mount Wilson Observatory, to Joseph Barrell and Charles Schuchert, of Yale University, who have kindly cooperated through correspondence and otherwise.

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THE RÔLE OF SERVICE IN EVOLUTION

By Professor HERVEY WOODBURN SHIMER
MASSACHUSETTS INSTITUTE OF TECHNOLOGY

SERVICE is an essential of life upon this earth. Compulsory it surely is in the vast majority of plants and animals, but it becomes more and more voluntary in the higher types of the invertebrate animals and finds finally its highest expression among the vertebrates in man.

When one organism is forced to yield its body for the nourishment of another it renders the grossest form of compulsory service. Yet all animals and many vegetable forms are dependent upon the death of other organisms for the prolongation of their own life.

"Life evermore is fed by death,
In earth and sea and sky;
And, that a rose may breathe its breath,
Something must die.

"The milk-haired heifer's life must pass
That it may fill your own,
As passed the sweet life of the grass
She fed upon."

To this compulsory service is due nearly all life upon earth and all opportunity for higher development. So that mere living rolls up the debt each individual owes to myriads of other individuals.

A higher type of compulsory service is seen in those organisms in which the production of young results in the death of the parent. This is the case in most herbs among plants and in many protozoöns and insects among animals. Though the organism is compelled to perform this service, it lives its allotted span and then dies; death is not a tragedy. Compulsory service is also rendered by the individuals of one generation to those of the next in the furnishing of food for the developing embryo; the storage of nutriment around the germ in all higher plants, the provision of yolk for consumption within the shell or other envelope in the higher invertebrates and in all vertebrates, except the mammals, as well as the interuterine nourishment of embryonic mammals.

In the instinct, however, which furnishes food and protection to the growing offspring we have, coupled with an involuntary service, a certain amount of the voluntary indicated by variability among individuals of the same species in the amount and kind of labor they expend upon their young. This variability, increasing in the higher types of animals,

is an indication that some individuals are beginning to put a small amount of choice into this service. In the solitary wasps, typified by Ammophila, individuals of the same species differ greatly in the amount of food they furnish their young. Some are good providers, others poor. Some also are exact and precise in all their movements, others are very negligent and disorderly, leaving their offspring less effectively protected in numerous ways.

There is similarly a high degree of difference among individuals of the same species in the vertebrate line from fish up to man in the amount and efficiency of voluntary service to offspring. Some sunfish, for example, will fight courageously to protect their rude nests, others are very timid. Some birds, though trembling with fright, will continue to sit upon and protect their eggs even when threatened with death, while other individuals of the same species desert their eggs or young upon the least approach of danger. The lower races of man, likewise, show their inferior stage of development most forcibly in the insufficient food and care they give to wife and children.

As we glance backward over the history of the earth from the present Cenozoic Era, through the Mesozoic and Paleozoic, we see that compulsory srvice was ever present; that many millions of years ago in the lowest Paleozoic the grosser kinds alone existed; that gradually through the succeeding ages higher types of compulsory service appeared, existing side by side with the grosser; that, finally, voluntary service evolved, and, developing very slowly, reached a degree worthy of the name only in the Cenozoic. These various types of service continued to exist side by side; and since it was the more highly evolved plant or animal group that exhibited the correspondingly high type of service these occupied the better regions of the earth, forcing the less highly developed to less desirable habitats.

That the consumption of other organisms for the prolongation of one's own life extends from the present to the early periods of earth history not only the testimony of tooth structure, claws, tentacles and other food-capturing organs testify, but a multitude of actual records prove. Skeletons of marine reptiles (Plesiosaurs) are abundant in the Mesozoic era, which show in the region of the body where the stomach was formerly situated, the crushed cells of pelecypods and ammonites, the internal skeletons of squids and the broken bones of flying reptiles. In the living chamber of fossil cephalopods also occur at times the hard shell and scale remnants of the diet of these animals; these are found from the lower Paleozoic to the present. The appearance of fish scales in the living chamber of lower Paleozoic individuals testifies to the welcome they gave the earliest fishes upon this earth.

Besides this gross type of compulsory service there was present by

mid-Paleozoic time the forced yielding of the parent's life for the production of young. There were probably many protozoons of which this was true, as it undoubtedly was of many corals whose remains have been preserved, as well as of the many herb-like plants with a single growing season. It was, on the whole, the lower plant or animal groups only whose life span was thus reduced; to the higher groups a longer life was a necessity. Such higher individuals had been evolved by mid and upper Paleozoic time and these were compelled to prepare a considerable amount of nourishment for the developing embryo. This was true of the primitive seed-plants, as well as of the early fish, amphibians and reptiles.

If we may judge by the most nearly related living forms, there must likewise have been present during the entire Paleozoic a rudimentary kind of instinct, with but a minimum amount of free choice and hence of voluntary service. Even the insects, first appearing in the upper Paleozoic and rapidly becoming so numerous in the vast coal-swamps of that time, all belonged to the lower orders with a very low degree of instinct.

With the evolution in the Mesozoic era of the higher seed-plants, insects and fish, and of the most primitive birds and mammals, a higher type of compulsory service was initiated and a distinct beginning in voluntary service made. The higher seed-plants, typified by the oak and hickory, furnished a larger amount of embryonic nutriment and better seed protection than did the primitive seed-plants of the upper Paleozoic. The development of bees, ants and wasps with the mid-Mesozoic was most probably accompanied with a beginning of that wonderfully evolved instinct and of some voluntary service to their young, as well as to the members of the community, which characterize their modern representatives. The incoming at the same time of the highest order of fishes, the Teleostei, may likewise have been accompanied in some individuals, as it is in many of their living descendants, by a certain amount of voluntary service.

Some of the Mesozoic mammals, allied to the existing monotremes, probably like these laid eggs, hatched them as birds now do and then suckled the young; while others, more nearly related to the kangaroos and insectivores were, in all probability, like their modern representatives, forced to protect and nourish the embryo within the body until well developed and after birth to continue this care by fighting off enemies and nursing the young. While all the service before birth, and much after it, was compulsory there still remained a distinct amount of voluntary service both in hatching the eggs and in feeding and protecting the offspring.

During the Cenozoic appeared the highest forms of service, both

compulsory and voluntary, yet developed on the earth. The production of conspicuous flowers, of nectar and other devices for the perpetuation of species of plants is a form of compulsory service originating mostly during the Cenozic, though undoubtedly some of these devices received their inception in the Mesozoic.

The development in the Cenozoic of the living groups of birds was accompanied, if it did not originate in the Mesozoic, with the hatching instinct. A considerable amount of this instinct is, however, voluntary service, since it differs so greatly among individuals of the same species or variety. After the young are hatched the parents are doubtless compelled by instinct to feed and protect them, but here again much of the service is without doubt voluntary. (Since the birds of the Mesozoic were reptile-like in the sharp teeth, claws upon the wings and long vertebrated tail possessed by most individuals, they may also have been reptile-like in their failure to personally hatch their eggs and feed and protect the young.)

The appearance of carnivore, rodent and hoofed mammals in the lower part of the Cenozoic initiated a much higher type of voluntary service. These mammals, to judge by their nearest living relatives, were compelled to serve their young before birth by interuterine nourishment and after birth through the secretion of milk. They also protected their young as well as their mates, and procured them solid food. They were doubtless impelled to these latter acts by instinct, but a considerable amount of voluntary service was present.

In the upper part of the Cenozoic appeared man, and with him began the development of the highest type of voluntary service yet evolved upon this earth. Slowly, extremely slowly, it advanced at first and was for long doubtless limited to the family; gradually, however, it was extended to other members of the clan, nation, language and finally even to the barbarian, heathen or gentile, and even to lower animals and to plants. Man is, however, still under the law of compulsory service. The unborn young must still be given interuterine nourishment and the young child food and care, while public opinion and man-made laws force the laggard to duties which he is not yet sufficiently evolved to perform voluntarily.

We thus see that the development of life upon this earth was due to mutual service, that without such service no higher forms of life could have evolved. Animals can live only through the death of other animals or of plants. Both animals and plants are compelled to give of their strength, or often of life itself, in the production of young. As animals and plants became more highly evolved they developed a higher type of service, that of furnishing more nourishment and better protection to their offspring. Very gradually, side by side with the higher kinds of

compulsory service, there was evolved a voluntary service; minute in kind and amount at first, it has finally come in the nobler members of mankind to dwarf the former by comparison into insignificance. Pre-Paleozoic time and the long Paleozoic era stand for low types of compulsory service; the Mesozoic for higher kinds of compulsory service with a definite beginning of voluntary service, while during the Cenozoic this latter type increased in amount until at present in man it far overshadows the service of compulsion.

Evolution as we see it upon this earth has thus occurred through each successively higher group, taking more and more from others, especially from parents, and giving more and more in return, especially to offspring; the service rendered is passed on, not returned. When, however, a plant or animal group takes more and more from others without giving aditional service in return, we have parasitism, and parasites are not now, nor were they in the distant past, in evolving lines. Parasites whether plant, beast or human are degenerate; the individuals become weaker and weaker and finally the life ends in death.

The trend of evolution has thus been from compulsory service to voluntary, from an enforced aid to others to help given because of love for others. Those lives develop most rapidly and nobly which most nearly conform to this trend.

THE RELATION OF HEREDITY TO CANCER IN MAN AND ANIMALS

By C. C. LITTLE

CANCER COMMISSION OF HARVARD UNIVERSITY

THE existence of hereditary tendencies or predispositions to cancer, in man, has been for years and still is a much debated question. In the face of a steadily increasing volume of evidence both *pro* and *contra,* not only laymen, but the medical profession as well are still of uncertain or divided opinions. Gradually, however, medical institutions have taken up the investigation of the problem until at present a considerable number of laboratories are engaged in experimental studies to determine the importance of heredity in the transmission of cancer. Because of this fact it may be of interest to consider broadly the relation of present genetic methods to the problem of human cancer. We may do this in the hope of determining in advance, if possible, the necessary limitations in applying such methods to the problem in question.

Two main lines of research in genetics may contribute data which have a definite bearing on the question as to whether or not there are hereditary tendencies to cancer in man. The first of these is a study of family histories in human beings themselves; the second is the experimental study of inheritance in the lower mammals.

The value of any data obtained must obviously be based on its scientific accuracy and on its applicability to the problem under consideration. We may now briefly consider the obtainable data in the two branches of research indicated and apply to them the test of value, above mentioned.

All data involving several generations of human beings are of necessity, under our present methods, based at least partly on "hearsay" evidence. The amount of data so obtained when compared with those obtained by direct observation will of course vary in different individual problems. It will, however, always be present as a source of fundamental inaccuracy.

There are many other minor, but none the less important, sources of error. Among these may be mentioned ignorance as to the exact cause of death or diagnoses based on clinical rather than autopsy data. Failure to give sufficient prominence to age, as an important factor, may further complicate the problem. Numerous similar conditions combine with those mentioned to make the data gathered from available sources entirely unreliable in determining the course of inherited tendencies to cancer in the human race.

The accuracy of the data obtained from experimental studies of the

smaller mammals is, on the other hand, sufficient to warrant reliance being placed upon them. Among the smaller mammals, none appear to offer material so favorable to the problem in question as do mice. Their short life cycle, rapidity of multiplication, convenient size and adaptability are supplemented by a varied and representative series of neoplasms serving to give them a unique value. Such studies as those of Tyzzer and Murray, and more recently those of Slye, Loeb and Lathrop, *have proved beyond question that hereditary factors play an extremely important part in determining the incidence of cancer in mice.* Though the *fact* of inheritance is undoubtedly established, *the method of inheritance* is as yet undetermined. Doctor Slye's work has repeatedly shown that non-cancerous parents may give cancerous offspring, and that cancerous parents may give non-cancerous offspring. This at once indicates a complicated type of inheritance, the exact nature of which is still in doubt.

Even in the case of inoculated tumors in mice, where our sole concern is *growth* of the tumor after its implantation, we have recently found that the interaction of many hereditary factors is involved (Little & Tyzzer, 1915).

Although smaller animals, as shown above, possess great advantages over man as material for studying the influence of heredity on the occurrence of spontaneous cancer, they, nevertheless, because of the fact that they are commonly genetically heterogenous, and because cancer is a disease influenced by sex and by the age of the animal, are not free from certain inherent limitations which make the analysis of the hereditary factors, beyond a certain point, extremely difficult. The only possible exception to this statement will be a race of animals so closely inbred as to be essentially homogeneous in its hereditary constitution. Various geneticists as, for example, Pearl and Jennings, have computed with accuracy the amount of inbreeding necessary before such a condition of homogeneity is closely approached. From their work it appears that many generations of continuous closest inbreeding, such as, for example, own brother and sister matings, must be made before homogeneity of genetic constitution is approximated. It is safe to say that none of the material thus far employed in investigations with spontaneous tumors meets this requirement.

Some doubt has been expressed as to the applicability of the results obtained with small mammals such as mice, for example, to the problem of human cancer. In so far as these results may affect the acceptance of the *fact of heredity,* doubts are not justified by analogy with any of the cases of inheritable characters, so far investigated. It is possible and permissible to argue the existence of hereditary tendencies to cancer in man on the basis of proved existence of such tendencies in other mammals. Similar arguments have been shown to apply to albinism, spotting, shape of hair, color of eyes, certain abnormalities in growth of the bones, and to many other characters.

It further appears that certain histories of human families are striking enough, even with present imperfect methods of obtaining data, to indicate strongly the presence of hereditary tendencies to cancer in man. Not only is this the case, but the problem may be approached from the opposite viewpoint and the data supposed to show the non-inheritable nature of human cancer may be examined. Such work as that of Pearson, and other biometricians, while adding little in accuracy to the methods of obtaining data on human inheritance, are guilty of a gross mistake in their method of analysis. Their weakness lies in the fact that they are able to detect only the direct or Galtonian type of inheritance and are utterly unable to recognize or utilize the well-defined and accepted principles of transmission by individuals of hereditary potentialities throughout an indefinite number of generations without any morphological manifestation of those potentialities until similar or otherwise suitable mates appear. Biometrical methods are of undoubted value, but they fall short of the whole truth, and can not in this case be taken as alone disproving the occurrence of hereditary factors in the case of human cancer.

An example of an actual case of inheritance in mice may serve to make clear the limitations of biometric methods of detecting even the fact of inheritance. All pigmented mice are classifiable into two groups, those having solid colored or "self" coats, and those having white spots of varying sizes. In other words, the mouse is either "self" or "spotted" *in appearance*. Supposing a mixed population of let us say 15,000 mice, some of which are "self," some "spotted," and let us try to prove that spotting is or is not inherited. Following certain biometric methods we shall consider the parents and grandparents of each spotted mouse as compared with the same ancestral generations of non-spotted ("self") mice.

Any of the following types of ancestry are possible and have actually been *repeatedly* obtained in the laboratory.

Mating	Mouse Observed	Parents	Grand-Parents
(a)	Self	Self	Self, Self
		Self	Self, Self
(b)	Self	Spotted	Spotted, Spotted
		Spotted	Spotted, Spotted
(c)	Spotted	Self	Self, Self
		Self	Self, Self

(*d*) Spotted	Spotted	Spotted
		Spotted
	Spotted	Spotted
		Spotted

Between these extreme types of ancestry every possible intergrade has been obtained again and again, so that if we happened by chance to pick matings of the types (*a*) or (*d*), or others approaching them, we should undoubtedly prove the inheritance of spotting to our own satisfaction. On the other hand, if matings (*b*) and (*c*) had happened to have been our experience, we should believe that no such inheritance existed. Generally speaking, a mixed population of spotted animals would form for biometric methods of analysis only confused and inconclusive material on which no conclusion of lasting value could be based.

It has, however, long been known that spotting in mice *is* inherited, and I have recently been able to account for and predict the occurrence of the spotted forms on the basis of the interaction of at least three pairs of hereditary factors showing Mendelian or alternative inheritance. In making the analysis of this problem it was fortunate that in certain races in the laboratory, only one or at most two of the three types of spotting existed together. This fact made possible the recognition of certain relationships between the different types of spotted coat which would otherwise have certainly escaped notice, and without which even an incomplete explanation of the facts would have been impossible.

The case of spotting in mice has been entered into at some length because of the fact that it proves the inadequacy of purely biometric methods to detect or explain a case of heredity even involving as few as three pairs of factors. Moreover, these spotting factors produce a series of forms recognizable in early life, and spotting, unlike cancer, is free from the effects of age, sex or any but the most radical environmental disturbances. To *disprove* inheritance solely by biometric methods in this simple case is impossible, and the same is certainly true in the obviously less simple case of cancer.

If now we turn to a consideration of the human beings as material and of certain facts concerning the biological nature of cancer, we can recognize the handicaps under which we must work, if we attempt to investigate the course of hereditary tendencies to cancer in man.

Biologically, cancer may be considered as consisting of a mass of tissue of local origin manifesting uncontrolled and unlimited growth. The problems of its etiology are therefore essentially those of the factors causing, limiting and directing cell division.

If we for a moment consider the cells of the animal body as units, we can picture the embryo of any mammal, at the gastrula stage, as consisting of essentially *two* types of slightly differentiated cells, ectoderm and endoderm. Each of the two types of cells may figura-

tively be considered as a "species" consisting of a number of "individuals" undergoing reproduction by the process of mitosis. There are two very distinct environmental forces in the life of such an embryo. One we may call the "external environment," as exemplified by the surroundings of the embryo, the other we may call the "internal environment" which includes the relationships between cells (individuals) *within* the embryo. During the gastrula stage the *internal* environment is relatively simple, but as the embryo grows we find that complexities appear one after another. As the number of cells (individuals) increase, we find that the number of *types* of cells (species) increase as well (differentiation of tissues). This may be considered largely the result of differences in the internal environment in which certain cells or groups of cells find themselves. Nutrition, and undoubtedly to a large extent internal secretions, play the leading parts among the influences of the internal environment.

The young mammal shortly before sexual maturity has thus reached a point where a steady process of cell division (multiplication of individuals) within many definite types of tissue (many species) is in progress. Now into this more or less balanced condition is introduced the secretions of the newly active sex glands, ovaries or testes, as the case may be. At once the internal environment is fundamentally changed. By the circulation the modifications introduced by these secretions are transmitted through the body, reaching all types of cells in all localities. It is as though in a given isolated geographic unit, populated by a fauna of many species, a certain food tree was introduced in great numbers in addition to the somewhat similar types of food trees formerly there. This new tree provides food which gives certain species of animals in certain localities more suitable nutrition than they have yet obtained. The result is rapid growth and reproduction of that particular species, while the others near it may be unaffected, or may even suffer by the rapid multiplication of the favored species.

It is obvious that changes in the internal environment will be frequent. The cyclic changes of the reproductive system, including also the changes of pregnancy and of lactation, undoubtedly represent fundamental upsets of the equilibrium of the internal environment. The same, of course, holds for retrogressive changes such as accompany the cessation of activity of the reproductive system and the progressive changes of approaching senility.

To any biologist, it will have long ago suggested itself to question the influence of the inherent physico-chemical nature of the cell material. Undoubtedly this is a matter of fundamental importance, for it is in the reaction of the cells to the influences and agencies of the internal environment that initiation, continuation and control of cell

division have their origin. It is also certain that hereditary differences in the nature of the cell material among animals of a single species exist. These differences will naturally be an important factor in the reaction of such material to a given stimulus of the internal environment. For example, we may imagine that a certain type of internal environment may cause the material within the connective tissue of individual (*a*) to show no abnormality of growth, while the material forming the connective tissue of individual (*b*) of the very same species may be inherently different to a point where an identical internal environment will start up uncontrolled growth.

On the other hand, two individuals may have connective tissue which is similar in respect to its reactions to a certain stimulus of given internal environment *X*, but may differ in their internal environments because of differences in amount or exact chemical nature of internal secretions or other important agents. In one animal, connective tissue *Y* might show no effects of internal environment *X*, while in the other the interrelation of connective tissue *Y* with environment *X′* might lead to uncontrolled growth.

This rather lengthy treatment of the subject of internal environment has for an object to emphasize the extremely complicated biological nature of cancer. Occurring as it does, usually in middle or old age, it is at a point most completely removed in time and space from the carriers of the elementary hereditary tendencies—the germ cells. In such an animal as man, where the average age for the appearance of cancer, broadly speaking, is about forty-five to fifty years, the opportunities for the effects of the internal environment to become excessively amplified and complicated are, of course, obvious. Injury as well as inflammation of long duration, long recognized as probable agents in the initiation of uncontrolled or abnormal growth, are also much more likely to be of importance in a very slow-growing mammal such as man, than in a rapidly growing mammal like the mouse. This follows from the fact that the *critical periods* in internal environmental changes in man are in themselves far longer in duration than they are in mice, and an injury or irritation, therefore, has more chance of occurring in one of these periods. In the cases of irritation or injury the inherited nature of the individual is of prime importance. A great number of men may use tobacco to an equal extent and yet only part of them may develop cancer of the buccal cavity. In such cases the irritating stimulus may be equal, but the nature of the reaction of the individual's tissue may differ widely.

Again and again we are driven back to the ground that the nature of the mouse, or of the man, by which we mean the nature of his hereditary living material, determines his physiological reactions to any given environment, and further we may add that it determines to a

large extent the behavior of the fundamental factors influencing his *internal* environment. As we attempt, however, to analyze the important hereditary factors, we are in man faced with certain limiting facts. Inadequate methods of observation, diagnosis and recording; magnified effects of environment due to a long life cycle; small numbers of young, and a deliberate system of out-breeding which completely mixes and confuses the material with which we have to deal, force us to the conclusion that studies of hereditary tendencies to cancer in man as they are at present carried on, will yield little, if anything, of value to the subject under consideration. We may further say that present indications are that genetic studies with lower mammals, while having proved definitely the existence of hereditary tendencies to cancer, indicate that a complex type of inheritance is involved which could at best be of negligible importance as a practical preventive or protective measure in man.

This may give the erroneous impression that genetic studies even with lower animals are superfluous in the field of cancer research. This would be most unfortunate, however, for it appears certain that the *etiology* of cancer is a problem of growth and differentiation and as such is essentially biological in nature. It may therefore be approached perhaps with marked success, through genetic investigations with rapidly breeding small mammals in which a study of the biological factors fundamentally important can, under proper circumstances, be best accomplished.

THE PROGRESS OF SCIENCE

THE EPIDEMIC OF INFANTILE PARALYSIS

THE epidemic of infantile paralysis centering in Brooklyn has not attracted more attention than it deserves, although the 2,000 cases and 400 deaths which had occurred up to July 18 are not large in comparison with the waste of child life to which we submit. About 200,000 infants and about an equal number of children and young people die needlessly each year in this country. That the deaths are due to ignorance and neglect is evident from the fact that three times as many children die in Fall River and Patterson as in some other cities. It is quite possible that through the vigorous hygienic and sanitary measures now being undertaken in New York City more lives will be saved than are lost through the epidemic.

The disease is startling through its comparative newness, its method of spreading, the futility of any treatment, its symptoms, the high death rate and the permanent after effects which may ensue. The best available account of the nature of the disease, the manner of its conveyance and the means of prevention, is contained in an address given before the New York Academy of Medicine on June 13, by Dr. Simon Flexner, director of the laboratories of the Rockefeller Institute for Medical Research, whose researches have contributed largely to what we know concerning infantile paralysis, or poliomyelitis, and spinal meningitis. Dr. Flexner tells us, in his address, which is printed in the issue of *Science* for July 21, that infantile paralysis is an infectious disease caused by an invasion of the spinal cord and brain by a minute filterable microorganism, which has now been secured in artificial cultures and is visible under the higher powers of the microscope. The virus exists not only in the central nervous organs, but also on the mucous membranes of the nose, throat and intestines. Less frequently it occurs in other organs and it has been found in the blood. The virus can be detected by inoculation tests upon monkeys, though with so much difficulty that ordinary bacteriological tests can not be employed for the discovery of the disease. In this manner it has, however, been determined that healthy persons may carry and spread the infection.

The virus of infantile paralysis leaves the infected patient through the secretions of the nose, mouth and intestines and enters the body as a rule, if not exclusively, by way of the mucous membranes of the nose and throat. Since epidemics of infantile paralysis always arrive during a period of warm weather, they have been thought to be connected with insect life. This has, however, been disproved, except in so far as domestic flies and other insects may serve as mechanical carriers. The paralytic diseases of domestic animals and pets are quite different from infantile paralysis and these animals must be acquitted of being hosts.

Infantile paralysis is one of the diseases in which insusceptibility is conferred by a previous attack and protection has been conferred on monkeys by inoculation with small amounts of the virus and by serum treatment. Promising results are said to have been obtained in France on men but the quantity of human immune serum is very limited and no animal except the monkey seems capable of yielding the immune serum, and the monkey is not a practical animal from which to obtain supplies. The only drug which has shown any useful degree of activity is hexa-

Pho ograph from Underwood and Underwood, N. Y.

ELIE METCHNIKOFF

The distinguished Russian Zoologist and Bacteriologist, since 1888 a Member of the Pasteur Institute, Paris. He died on July 15, aged seventy-one years.

methylenamin, but in monkeys this has proved effective only very early in the course of the inoculation and only in a part of the animals treated. The epidemic must be controlled by general sanitary means, though medical and surgical care may assist in recovery. Protection can best be secured through the discovery and isolation of those ill of the disease and the control of those persons who have associated with the sick and whose business calls them away from home. The usual means by which the secretions of the nose and throat are disseminated are through kissing, coughing and sneezing. The early detection and isolation of infantile paralysis in all its forms with the attendant control of the households from which they come is the chief measure of staying the progress of the epidemic.

CINCHONA AS A TROPICAL STATION FOR AMERICAN BOTANISTS

Professor Duncan S. Johnson, of the Johns Hopkins University, it will be remembered, contributed to the Popular Science Monthly (December, 1914, and January, 1915) two illustrated articles on the Cinchona Botanical Station. He now writes to *Science* that it is practically assured that some fourteen American universities, botanical foundations and individual botanists are to cooperate with the Jamaican government in the support of Cinchona as a tropical station. A move to aid in the support of Cinchona, initiated by the Botanical Society of America in 1912, was not consummated, in consequence of the earlier leasing of the station to the British Association for the Advancement of Science. The Jamaican authorities and the British Association seem quite willing, under present conditions, to allow the lease to pass into American hands after October next.

The attention of American investigators should, therefore, be directed to the facilities for botanical research offered by this oldest and best known botanical laboratory in the western tropics. Among the advantages of this station for American botanists are the greatly varied flora and series of types of vegetation; the proximity of a library and of two other botanical gardens, beside that surrounding the laboratory. The location of Cinchona is a very fortunate one for American botanists from a practical standpoint. It is in an English-speaking country with good roads, a stable government and adequate quarantine service. It is also within easy reach of our eastern seaports, from several of which the round trip to Jamaica and Cinchona can be made in summer for $75.00 or less for transportation. It is altogether probable that any American botanist wishing to work at Cinchona will be granted the privilege by requesting it of the colonial government of Jamaica through Superintendent William Harris, F.L.S., Hope Gardens, Kingston, Jamaica.

Dr. C. H. Farr of Columbia University calls attention to the fact that a tropical rain-forest presents peculiar conditions. The plants do not show the marked periodicity characteristic of colder and dryer regions. Where the temperature and rainfall are so nearly constant at all times of the year as at Cinchona, one is likely to find all of the stages in the life history of a species on almost any single day, and conditions are favorable for collecting the year around. To the cytological collector a compound microscope is an absolute necessity; and such a permanent station as that at Cinchona, therefore, seems to be the only solution to the accessibility of such regions. The buildings at Cinchona, including two cottages, a two-room laboratory, the drying house, the dark room, the greenhouses and the garden, were all in good condition when he left there in December last. Through the kind offices of Mr. William Harris at Hope Gardens servants were made available, and his personal needs adequately

supplied. The space is sufficient for a number of investigators at one time, and life there is very pleasant indeed.

Dr. Forrest Shreve of the Desert Laboratory of the Carnegie Institution writes that the portions of the Blue Mountains which are accessible from Cinchona, at both higher and lower altitudes, exhibit a diversity of vegetation in correlation with the widely differing temperature and moisture conditions, and also a vertical diversity from floor to canopy within the rain-forest itself. Ample opportunity is thus offered for the investigation of the physical environment in relation to the local and general distribution of plants. A wide range of plant material is available for the study of general physiological behavior as well as for the special types of activity characteristic of rain-forest plants. The fundamental processes of plants, as carried on under extremely humid conditions, and the influence of the character and rate of these processes upon the growth, distribution and periodic phenomena of the hygrophytic vegetation offer a rich field for future work at Cinchona. The gardens, greenhouses and various outbuildings afford opportunity for propagating plants and for placing them under a variety of experimental conditions. The nearness of an extensive tract of virgin forest is also a valuable asset for physiological as well as ecological work. The excellent trails, the easy means of communication and supply, the presence of a guide with a knowledge of the local flora, and the very healthful living conditions combine to make Cinchona an extremely useful station for those who may wish to carry on more or less prolonged investigations in the problems of the semi-torrid and humid tropics.

IRRIGATION IN BRITISH COLUMBIA

One of the strongest conservation fights in all America is being waged in British Columbia where the destruction of the forests on the Rocky Mountain slopes through continual fires has imperilled many thousands of acres of farm land in the valleys. Hand in hand with these efforts of the provin-

An Irrigation Flume in British Columbia. Summerland District.

APPLICATION OF THE WATER TO THE TREES, SHOWING METHOD OF IRRIGATION. The water is generally put on to the highest point of an orchard by the company and from there the fruit farmer distributes it all over his orchard, as shown in this photograph.

A VALLEY RECLAIMED. Summerland District of British Columbia under irrigation.

cial government is the work of the irrigation companies, which number nearly three hundred in the province; most of them, of course, control only a few miles of pipe lines and have a low capitalization. The largest irrigation project in Canada is at Bassano, Alberta, and in it the Canadian Pacific Railway has already invested $10,000,000. Whatever the dimensions of the company, however, the fact that its revenues depend upon a supply of water from the hills and the additional fact that stripping the hills of timber growth ruins the water supply, brings to the side of forest protection a very strong influence.

In the interior of British Columbia, from which the accompanying photographs were taken, irrigation has reached a high degree of perfection. Barren lands were bought up by companies at a few dollars an acre and resold at a thousand dollars an acre. Those who have bought at these prices have in numbers of cases made large profits from fruit cultivation. The growth of fruit trees and of the fruit is very rapid because of the steady supply of moisture, although the quality of the product is regarded by many as not quite equal to that of non-irrigated lands.

SCIENTIFIC ITEMS

DR. CHARLES HORACE MAYO, of Rochester, Minn., was elected president of the American Medical Asociation at the recent Detroit meeting. Dr. William J. Mayo, his brother, was president in 1906.—Dr. Henry M. Howe, emeritus professor of metallurgy in Columbia University, has been appointed honorary vice-president of the Iron and Steel Institute of Great Britain.—At a meeting of the Texas chapter of the Society of the Sigma Xi, on June 5, Dr. Frederic W. Simonds, professor of geology in the University of Texas, was elected president for the year. Dr. Simonds was one of the first five graduate students elected to membership in the Cornell chapter.

THE International Health Commission of the Rockefeller Foundation, sent to Brazil to make a general medical survey of the southern part of the country, has returned. The commission consisted of Professor Richard M. Pearce, of the University of Pennsylvania, chairman; Major Bailey K. Ashford, of the U. S. Medical Corps; Dr. John A. Ferrell, of the International Health Commission, and a secretary. They were absent for about four months and the work included a study of the general educational system in Brazil, the medical schools, hospitals and dispensaries, and public health organization.—The Carnegie Institution expedition to Tobago, British West Indies, was exceptionally successful. The southwestern end of Tobago consists of elevated coral-bearing limestones and the coast from Milford Bay northward is flanked by a modern coral reef. Dr. Hubert Lyman Clark, of Harvard University, collected 73 species of echinoderms in this region, and of these Dr. Th. Mortensen, of Copenhagen University, reared 10 throughout their larval stages; among them a crinoid Tropiometra which was abundant over the shallow reef-flats. Dr. A. G. Mayer studied the Siphonophores, the pelagic life being abundant, due to the fact that the water of the great equatorial drift of the Atlantic strikes immediately upon the coast of Tobago. The coastal waters of Tobago are those of the clear blue tropical ocean, for the island lies to the northward of the muddy shores of Trinidad.

Vol. 3, No. 3 SEPTEMBER, 1916

THE SCIENTIFIC MONTHLY

EDITED BY J. McKEEN CATTELL

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THE SCIENCE PRESS

LANCASTER, PA. GARRISON, N. Y.

NEW YORK: Sub-Station 84

Single Number, 30 Cents Yearly Subscription, $3.00

THE SCIENTIFIC MONTHLY

SEPTEMBER, 1916

THE SCIENTIFIC INVESTIGATION OF CANCER

By Dr. LEO LOEB

WASHINGTON UNIVERSITY MEDICAL SCHOOL

WE may treat the subject of cancer from two points of view, namely, from that of the scientific investigator who studies it as a natural phenomenon and ascertains the laws of its origin and development, and from that of applied science, medicine, which is mainly concerned with the eradication of the disease. In the natural course of events, scientific analysis must precede the utilitarian attempts at control. I shall treat the subject of cancer purely from the viewpoint of scientific analysis. This analysis is not yet completed and on this occasion I shall endeavor to tell something of what science has discovered about cancer, following a study which really does not date much further back than twenty years.

Scientific investigation starts with the most obvious and gradually penetrates into the more remote. Experiences are the starting point for investigation; experiences that call forth pain or pleasure, especially those that call forth pain, which do not fit into the rest of our life, which disturb its real or imagined harmony. In its origin, therefore, science is utilitarian. It is a direct struggle with the enemies of our peace of mind and of our body. Only gradually, through the greater maturity of our experiences, does reality become the object of our interests in this struggle with the emotions, and from now on we are no longer guided directly by them in our investigations, but the latter become transformed into a dispassionate search for the relations of facts. We seek to complete the picture of reality which at first was only a by-product of other efforts. This now becomes our real problem. The investigations have passed beyond the primitive, utilitarian stage. Eventually, however, this study of reality for its own sake leads to results which again serve our utilitarian purposes better than a direct attack of the problems from a so-called "practical" point of view. Wireless telegraphy, diphtheria antitoxin, the eradication of yellow fever were possible only on the basis of purely scientific analysis, such as is carried on in the case of cancer research at the present day. The

greatest technical progress has been accomplished and may be expected to bring the best results in the future by attacking the problem on the basis of a dispassionate philosophical analysis of reality. This analysis transforms thunder and lightning, which at first called forth only feelings of awe and fear, into phenomena of electricity, acoustics and optics, and teaches us their oneness with the phenomena which help to maintain life. The growth of bacteria, which cause disease and death, on the one hand, is seen to play a wider rôle in the economy of life, to be indispensable for the maintenance of life in the higher animals.

It is not otherwise with the subject on which I have been asked to write. What at first we consider a disease, a scourge which fills us with fear and despair, will be seen to be but a particular phenomenon of growth comparable in a certain respect to the development of the egg into the adult, to the restitution of an extremity in one of the more primitive amphibia and to the healing of the wound in a human body after a cut or a bruise.

In cancer we deal with an essentially similar phenomenon—with the multiplication of the small units of our body, the cells. In a definite, usually sharply circumscribed and relatively small area such cells begin to proliferate; they multiply to an unusual degree; they make their way into the deeper parts of the body, destroy the neighboring tissues, penetrate often into lymphatics or blood vessels, are carried to distant parts of the body—lung, liver or elsewhere—settle here and give origin to secondary growths, the so-called metastases. Not all new formations of this kind, which are generally called tumors, are equally destructive. Some merely grow slowly and form a prominence without penetrating into neighboring tissues. These are the so-called benign tumors. The destructive tumors are called cancers. Almost any tissue in the body, almost any cells may, under certain conditions, begin to grow in this malignant, cancerous manner and, according to the kinds of cells that have thus proliferated, different types of cancer have been distinguished, as, for instance, *carcinoma*—the cancer of the cells covering the surface of the body and the body cavities, the epithelial cells; and *sarcoma*—the cancer of the tissues connecting the various surface and glandular structures of the body. But these are, for our purposes, differences of minor importance. The essential fact is this: in cancer we are dealing with a cell multiplication similar to that which leads to the building up of the normal organism, the difference between normal growth and cancerous growth being as follows:

During the development from the egg to the adult organism, the multiplying cells and the developing tissues show a definite relation to one another, which is essentially hereditarily fixed. In cancer, however, certain cells or tissues fall out of this normal scheme of predetermined

growth; they are no longer kept in bounds through the agencies which restrain the development of other parts of the body, and this leads to the formation of monstrosities. We may then conclude that the same laws which ultimately determine all cell and tissue growth also underlie cancerous growth. These laws are fundamentally those regulating the physical and chemical changes which take place in the protoplasm. But added to these *general* causes of growth, which cancer has in common with embryonic development and the process of repair after the loss of parts of the body—the so-called regenerative growth—there must be a special factor which is responsible for the excessive growth-energy and destructive capacity of certain tissues or cells in the body which distinguishes them as cancerous growths from other kinds of growths. To find this special factor or rather this special set of factors constitutes the fundamental cancer problem.

In my introductory remarks I stated that certain experiences in life of a more or less emotional character are the starting point for investigation, and that only gradually do these investigations become dispassionate, objective, do they come into contact with neighboring fields of research and broaden into an attempt to understand reality. Hand in hand with this enlargement of the concept of the problem we find a simultaneous widening of the range of objects now considered as more or less related to the original object of investigation, and a greater refinement in the methods of research. At first only human cancer was considered. It is only recently that we turned with interest to other organisms and discovered that cancer exists in all classes of vertebrates—although with unequal frequency—and that somewhat related phenomena are even to be observed in plants. At first we were satisfied with the observation of human tissues with the naked eye and with statistics concerning the frequency and distribution of human cancer; later there were added microscopic investigations with gradually accumulating refinements. These in turn were reinforced with experimental methods in which were recorded observations of the growth of cancers in animals which had been inoculated with tumor. And then we began to study experimentally the conditions under which cancer developed spontaneously and under which the development of spontaneous cancer can be prevented in animals, and the reactions of normal tissues under various abnormal conditions.

The experimental study of cancer is as necessary as the experimental study of all other problems. Mere observation confronts us usually with a considerable number of variable factors, and when we observe a sequence to a certain group of factors, observation alone does not usually permit us to decide which factors are really causative and which merely accidental. Through experiment we can at will isolate or combine various factors and thus alone find the real causes. Ex-

perimentation in the case of cancer does not only consist in the artificial inoculation of cancer—which, by the way, is technically not very different from the injections of substances under the skin in human beings, and therefore not very painful—but also in the systematic breeding of certain animals and in varying the conditions of life in which animals are kept. In this way problems can be solved whose solution can hardly be attained if we restrict ourselves to observations of human cancer, because of the complicated conditions found in human society.

We have now determined what is meant by tumor and cancer, the general distribution of cancer and the methods of investigating the cancer problem. Let us then follow the threads of investigation a little farther and consider some of the results obtained by experimental means. Here we will take up in turn the three problems, namely, the conditions that lead to cancer, the reaction which takes place in the body against cancer growth, and lastly some properties of cancer cells—and secondarily of normal cells—which have been discovered as a result of cancer investigations.

In analyzing the origin of certain phenomena, we are apt to take one definite circumstance as the cause of a succeeding event. This is the procedure which we usually follow in our daily life. But a more careful analysis of any phenomenon will usually reveal to us the very much more complicated relation it bears to other phenomena. The more we search, the more apt we are to find that there are a number or rather a multitude of factors which at the very beginning work together, shaping the event which interests us. Among these factors we can discern some which seems to us of greater importance, more specifically related to the event under discussion and others which apply not alone to this specific event or to a relatively restricted number of events, but equally well to a large number of other experiences, not necessarily related to the one under consideration. For instance, to mention a factor belonging to the second category, the temperature which is required to sustain life processes in general and therefore also in particular cancer growth. The relation between temperature and cancer growth is therefore not a specific one, but one which cancer growth shares with other life processes. While a certain temperature, then, is one of the conditions necessary for the development of cancer, it is not a specific condition and therefore not a cause in the strictest sense of the word.

We know that not one single factor is the cause of cancer, but we have discovered a number of conditions all more or less specifically related to cancer growth. Provisionally these may be divided into two classes, namely, internal and external factors. By internal factors we mean such as are operative within the organism, apparently conditioned

mainly by the organization of the animal and at a place not accessible to a direct experimental change. The external factors consist of conditions operative in the environment of the cells which give origin to cancer, either within or without the whole organism of which the cancer cells form a part. The external factors are more accessible to experimental control than the internal. The external factors which set up changes in the cells and tissues are usually only the first link in the chain of circumstances which ultimately ends in the production of cancer. And this link we may generally call a *stimulus*.

Let us then first consider some of the internal factors and later the external factors which lead to cancer growth. One of the most important internal factors which has been thoroughly established within recent years, at least in the case of animal cancer, is heredity. Our attention was first drawn to the possibility that heredity might play a part in the origin of cancer, through observations which we as well as other investigators, made some eighteen years ago. It was found that a surprising multiplicity of cancers occurred in certain cages in which animals were kept, especially rats and mice, and that the varieties of cancer which appeared under those conditions were in each case identical. This led to the conclusion that cancer was so often found in those cages because the animals living there belonged to the same family.

There are other possible explanations for the frequent occurrence of cancer in animals kept in the same cage or breeding place. It might have been that the cancer spread through infection from one animal to another. Indeed, in the case of man, the alleged greater frequency of cancer in certain regions has been explained by some observers on the basis of the infectiousness of cancer. However, I may state here that no undisputed case, in animals or in man, has ever been recorded where cancer was known to have spread through infection caused by a microorganism. This lack of infectiousness, however, does not entirely exclude the possibility of the presence of microorganisms in certain cancers—a possibility to which I shall have occasion to refer later. There are certain cases in which metazoic parasites are undoubtedly responsible for the so-called "endemic" occurrence. We have, however, been able to decide the question as to the usual cause of the occurrence of identical cancerous growths in animals by showing that hereditary conditions play a paramount rôle. For this purpose we used mice, which are perhaps most suited to such experiments, since they are not long-lived animals. We kept them in families separated from each other throughout a number of years, but otherwise absolutely under the same conditions as far as climate and food were concerned. Now we found that each family had a definite cancer rate which remained approximately *constant throughout succeeding generations*. While in some strains cancer

occurred in about 70 per cent. of all females, in others it occurred in only 2 to 3 per cent. If we crossed two mice belonging to strains with different cancer rates, we found that in a considerable number of cases the offspring followed approximately the cancer rate of the parent with the higher cancer percentage; in other cases, however, the offspring followed the parent with the lower cancer percentage. *There is therefore not the least doubt that cancer in animals is hereditary.* And not only is the cancer frequency hereditary, but *also the* age at which cancer most frequently appears in each family. The hereditary transmission of the cancer age is independent of the frequency. Thus it may occur that if we compare two families we may find that cancer is about equally frequent in both, but that it appears in one most frequently in middle life, while in the other it usually develops in later life. And these conditions are constant in succeeding generations.

Does this conclusion apply equally to cancer in man? The complicated conditions in human society make it very difficult to interpret statistical data with the same definiteness as in the case of animals. There are, however, indications which make it very probable that *in man also heredity is a definite factor.* We know that some races are almost immune to cancer, as, for instance, the American Indian, the Negro in Africa, and some aborigines of Australia and the South Sea Islands. It is very probable that this immunity to cancer is not due to the differences in food or to climatic conditions. Europeans removing to these regions are not immune. Furthermore, we note that the negro in America has a much higher cancer rate than the negro in Africa. This may possibly be referable to the interbreeding which has taken place among the negroes and whites in this country. Definite data for man which could answer this question are, however, lacking, and until more exact investigations in this direction can be undertaken we must abstain from making final decisions as to this point. The observation that among white people the cancer rate differs relatively little in various civilized countries does not speak against the existence of a heredity factor. It might merely indicate that the hereditary disposition to cancer is about equal in different families or strains. Furthermore, in human society intermarriages have been so constant and so frequent that differences between various families which might have existed to a greater degree at earlier stages of development may gradually have been eliminated or obscured. It is, however, well known that in certain human families cancer has been very frequent. Only recently a very interesting observation was published concerning two sisters, who died within a very short time of one another, and were both found to have been affected by the same *very rare kind* of cancer. While it is perhaps possible to explain all such occurrences among human beings as referable to the laws of chance, the facts established

in the case of animals rather suggest that in human cases too heredity may be an important cause.

There are other conditions which may under certain circumstances act as internal factors. In the human being certain very peculiar tumors are found which by their general appearance recall the structure of embryonic tissues. By embryonic tissue we mean those structures which are intermediate between the ovum and the adult organism. These tumors are therefore called embryomata and they are found especially within the generative glands. It has been recently observed that eggs within the generative glands may begin spontaneously to undergo a certain development—to develop without fertilization. According to our observations such a development may proceed even to the early formation of the central nervous system. Such structures are, however, usually destroyed after a period of temporary growth; but it seems that under certain conditions they can develop into malignant tumors, malignant embryomata, or teratomata. The factors therefore which favor the fargoing parthenogenetic development of the ova must be considered as in some cases playing the part of internal factors leading to the production of cancer.

Developmental malformation is a third factor which may cause cancer. These tumors are frequently found at an early age, but they may become apparent only in later life. In either case they originate during the period of embryonic development. We know that developmental errors are not infrequently found in man as well as in animals. Not rarely cells are misplaced, partly or entirely separated from the normal environment. In most cases such abnormally placed cells do not result in serious consequences, but, in some, as we have said, they become the starting point for malignant tumors. Pigmented moles may be considered as developmental errors and it is a well-known fact that under certain conditions favorable to cancerous growth they have become malignant tumors. Thus again *indirectly* may heredity play a part in the origin of cancer.

External Factors

Let us now briefly consider the external factors to which we referred. Generally speaking any mechanical stimulus acting over a long period of time and leading to inflammatory conditions may produce cancer. Thus we know that long-continued burning of the skin by carrying stoves, as the natives of Kashmir do, and long-continued action of Roentgen rays, extending over a number of years without the available precautionary means, have led, in many cases, to the production of cancer. Chemical stimuli also may lead to cancer. It is well known that in certain trades cancer is more frequent because of the action of the chemicals used. Paraffin workers are not rarely affected by cancer

of the skin; aniline workers develop cancer of the bladder. But more interesting than these general chemical actions is the fact that certain chemical substances given off by organs within the body which normally have a stimulating action on the growth of certain tissues may on the strength of this stimulating action be factors favorable to the development of cancer. Thus it has been recently demonstrated that extirpation of the ovaries in animals at a certain period of their life may greatly reduce the occurrence of cancer of the breast in those animals. This is, in all probability, due to the fact that a certain substance given off by the ovary which normally stimulates the growth of the mammary gland is removed through the extirpation of the ovaries. Apparently any external condition which causes long-continued growth processes in cells may in consequence of this stimulating action be a factor in the origin of cancer, and if we learn to eliminate such action we may to some extent prevent the development of cancer in a certain percentage of cases.

We have now learned of a number of causes for this abnormal cell proliferation which we call cancer. We know furthermore that internal and external factors must cooperate in the development of cancerous tissue. But it is very probable that the ratio between the number of internal and external factors necessary to obtain definite results is not fixed. The larger the number of external factors the smaller, in all probability, need the requisite number of internal factors be. For instance, it is probable that very long-continued action of Roentgen rays may lead to the production of cancer in persons in whom the heredity factor may be very weak.

Stimuli, such as those which lead to the production of cancer, chemical as well as mechanical, also cause growth processes in normal tissue. We know that in lower animals parts of the body which have been lost, may be replaced; that in higher animals wounds will heal; that certain chemical substances call forth growth processes which are not cancer. For instance, the placenta, through which the fetus is attached to the mother, grows in response to a combined action of chemical and mechanical stimuli; ova can develop parthenogenetically (without fertilization) under the influence of various stimuli. But in all those cases the stimulus leads to only a temporary proliferative activity of the cells and tissues. Sooner or later, the tissues return to their former equilibrium in which proliferation is very limited or entirely absent. It is not so in cancer. Cells which through various agencies have once become cancerous may be destroyed; but where they are not exterminated, provided sufficient nourishment is obtainable and other conditions necessary to their growth permit it, they proliferate eternally. Cancer cells, then, differ from normal cells in so far as the stimulus which in normal cells produces only a temporary growth, in the

cancerous transformation produces an endless increase in cell proliferation. In most cases cancer cells as well as normal cells are, as far as we can determine now, potentially immortal, which means that, given proper conditions for existence, they can live indefinitely and survive indefinitely the organism of which at one time they formed a part. Certain normal tissues may also not only live indefinitely, but also grow indefinitely, and cancerous cells differ from normal cells merely in their excessive proliferative function and in their greater power to attack the deeper tissues. This surplus power has been attained under the influence of the external stimuli which we mentioned before, with or without the cooperation of the internal factors.

The essential problem then is: How does it come about that under certain conditions stimuli which apparently are only temporary lead to changes which continue indefinitely after the stimulus has ceased to act? We must assume then that the organization of the cell has changed from one equilibrium—that of the normal cell—to another, which latter is characterized by greater proliferative activity and a greater power to penetrate into deeper tissues. The organization of some cells has been changed under the influence of growth stimuli and they are now somehow machines of a different character, which react differently to external factors. We might call such a transformation a mutation, and we have analogies for such a change in similar transformations which may suddenly occur in germ cells and lead to the production of new varieties and species. We have also in the case of ordinary tissue cells (in contradistinction to germ cells) some evidences that certain changes induced by external factors may be transmitted at least in some degree to succeeding generations of ordinary tissue cells. This is true of tissue cells as well as of germ cells; for tissue cells are potentially similarly affected as cancer cells. It is obvious then that one explanation for the origin of cancer may be the following. All or almost all normal cells possess two equilibria: (1) the equilibrium which is manifested under ordinary conditions, in which the cell has a limited proliferative power and (2) an equilibrium in which the cell has a greater proliferative power. A normal cell which has been changed from the first to the second equilibrium we call a cancer cell.

There is, however, another alternative in explaining the cancerous transformation, which would in certain respects furnish a simpler explanation. If we assume that in addition to the conditions which are important for the origin of cancer (namely, the internal and external factors before mentioned), there is hidden a constantly acting stimulus within the tumor, then the reaction of the tumor cell would be essentially similar to that of any normal cell. The tumor cell would react constantly through an increased proliferative activity merely as a result of an eternally acting stimulus. Such a continuous active stimu-

lus working through an agent external to the cancer cell could only be supplied by a microorganism constantly at work within the tumor. By microorganism we mean a very small living organism of either plant or animal character which can be seen only microscopically and which is sometimes so small as to escape detection even under the microscope. The smallest organisms of this kind are able to pass through a filter which retains ordinary bacteria. We know, in fact, that certain microorganisms may cause tumor-like cell proliferations, especially in plants. Certain plant tumors have been shown to be definitely caused by bacteria. In the case of animal tumors the proof that microorganisms are present has so far not been definitely established. We know, however, of very interesting experiments in which tumors have been produced artificially without a transfer of the tumor cells themselves. In ordinary experiments we can readily transfer tumor cells from one individual to another, of the same species, and thus cause in the second individual the growth of the same kind of tumor. Above, in speaking of these artificially produced cancers, I had not in mind the sort that are produced by transmission of cancerous cells, but I referred especially to experiments carried out by Peyton Rous with certain *bird* cancers in which *filtrates* of the bird cancer *free from living cells* appeared to call forth the production of new similar tumors. There are other experiments on record in which the introduction of one kind of tumor stimulated the cells of the animal to the production of another kind. These results can be explained only in one of two ways: either extremely small microorganisms were transferred with the tumor filtrate, or a certain chemical substance which stimulated the tumor cells to proliferate and which was constantly produced within the tumor cells was transferred with the filtrates, or, in other cases, with the living tumor cells, into the other individual and there produced the new formation of tumors. It is very probable that it will be possible to determine experimentally which of these two alternatives is correct, and thus arrive at a definite conclusion of the problem which we are seeking to solve. This will be the last link in the chain of factors determining the origin of cancer.

It is therefore not justifiable to state, as has been constantly affirmed only a few years ago, that the cause of cancer is unknown to us. In fact, we do know perhaps the principal factors with the result that in animals at least we can decrease or increase at will the cancer rate of certain strains by regulating the factors which we have analyzed so far. The next step will be to determine whether extremely small organisms or chemical substances are present in addition to the known factors. But even if we should have answered this last question, new problems will arise as to the manner in which chemical agencies (through which probably also microorganisms would ultimately act on the cells) can cause cell proliferation. And with this problem cancer research will

have reached common ground with general biology. The question of why certain stimuli cause certain cells to grow is one of the most important and far-reaching problems of general biology, since it is fundamental for both plant and animal life.

Equally important from the general biological point of view is the question of how heredity can determine whether or not certain external agencies will be more or less effective in changing the growth processes of a certain organism. But here also the problems of the origin and growth of cancer are in closest relation with other problems of biology.

To recapitulate then briefly what we know about the causes of cancer, we may make the following statment. We know the principal internal and external factors which cause cancer. We can experimentally modify or manipulate the internal and external factors in such a way as to change profoundly the cancer incidence in certain animals. By making appropriate matings between families of mice we can at will produce strains rich in cancers and strains poor in cancer. By changing internal secretions we can in certain strains of mice reduce the cancer rate from as much as 60 or 70 per cent. to nine per cent., provided the experimental interference is carried out at an early period in life. The problem which is not yet definitely solved concerns the manner in which those external and internal factors combine to cause cancer. We saw that there are two possibilities: It is possible that these factors cause a transformation of one cell equilibrium into another—the cancer equilibrium—and this would in the main differ from the cell equilibrium of ordinary life in the new production or in the greater production within the cells of the specific substance which causes abnormal growth. The same substance which would be newly produced in cells in the new equilibrium would also if injected into other animals of the same species, cause the transition of a cell from normal to cancerous equilibrium. In other words, through injection of those substances it is possible to produce a new cancer experimentally.

The second possibility is as follows: The external and internal factors which we mentioned make it possible for microorganisms to enter the tissues and to cause a transformation into cancer, or else they make it possible for a microorganism that has entered the tissues to initiate cancer growth. We are justified in believing that it will in the future be possible to decide between these two alternatives and thus to complete the solution of the problem.

Let us now turn to another phase of the cancer problem and try to answer the question, "Does the body that is invaded by cancer cells react against the cancerous growth; are in other words any mechanisms of defense apparent in the animal in which cancer is growing?" Before answering this question we must emphasize the very great distinction which exists between the spontaneous cancer, which has so far

been our main consideration, and the experimental cancer. In the latter we have to deal in almost all cases with a transfer of cancerous cells from one animal to another, while in the spontaneous cancer some of the cells of the animal itself become cancerous. In experimental cancer, then, usually cells of another animal grow within the inoculated individual. This distinction is of great importance when we come to consider the defensive mechanisms that arise within the body of the animal against the inroads of the cancer cells. We may briefly point out that spontaneous defensive mechanisms arise only in the case of experimental tumors (experimental tumors are foreign cells introduced into another organism and growing there), the body does not react defensively against spontaneous tumors. It is important to note that the defensive mechanism provided by the body against the attack of cancer cells can be artificially increased. This ability to bring into action defensive mechanisms we call immunity. The immunity produced in the case of experimental tumors, is, under ordinary conditions, not an immunity directed against the causative agent of the tumor associated with the cells and being either, as we have seen, a certain chemical body or a microorganism, but against the transplanted cells. Usually no immunity can be produced in the organism in which the cells have originated. But immunity can be produced against cells that are foreign to the organism—transplanted into it. The phenomena with which we deal in the process of tumor immunity are therefore not peculiar to tumors, but are the same in every case of transplantation of tissues. No defensive mechanism is developed in the individual against the cells of his own body, only against foreign cells. Thus if we excise a bit of skin or of the thyroid gland or of the uterus and place it in a pocket under the skin, the tissue remains preserved almost intact for a long period, probably during the entire lifetime of the individual. But if, on the other hand, we transplant a piece of skin from another individual of the same species, we find that the tissue is, after a longer or shorter period, destroyed within the new host. If we make careful microscopic examinations of tissue transplanted into a new host, we find that certain cells which circulate in the blood and lymph emigrate from the vascular channels of the organism in order to invade and gradually destroy the transplanted tissue. Other cells of the host also exert a deleterious effect on the foreign tissue and contribute to its final destruction.

If, instead of transplanting tissue from one individual to another of the same species, we inoculate an individual of a different species the tissue usually perishes directly through the influence of the body fluids which are poisonous for the transplanted tissue.

How can we explain these facts? We must assume that every individual of a certain species differs in a definite chemical way from every

other of that species, and that in its chemical constitution an animal of one species differs still more from an animal of another. Every cell of the body has a chemical character in common with every other cell of that body and also in common with the body fluids; and this particular chemical group differs from that of every other individual of the species and to a still greater degree from that of any individual of another group or species. Thus it happens that cells belonging to the same organism are adapted to all the other cells of that organism and also to the body fluids, but when transplanted into another organism, that specific substance which is peculiar to the individual is more or less toxic, or poisonous, for the new host, and causes the latter to react defensively against it by producing new substances which appear in the circulation and change the transplanted tissue. The transplanted tissue thus modified seems to exert an attraction for certain cells of the new host which hasten to the place in order to attack it. Or perhaps the transplanted tissue is directly altered by the foreign-body fluids and as a result defensive cells of the host are called into action.

Conditions are very similar when we deal with tumors instead of with normal tissue. Tumors which originate spontaneously in a certain individual can usually be transplanted without difficulty into another place in that individual. The cells remain alive and continue to multiply at the new place; but cells of a tumor when transplanted into another individual of the same or different species are destroyed, just as we saw was the case with the normal tissue. At this point, however, there is a difference between normal and cancerous tissue. While normal tissue in all cases is destroyed sooner or later after transplantation into another individual, there are *certain* tumors which in contradistinction to the large majority of tumors will grow in another individual of the same species after transplantation and sometimes even in an individual of a nearly related species. While structurally these *transplantable* tumors behave like other tumors, they differ from the large majority and from normal tissue in that they show a decreasing sensitiveness to the toxic action of those substances which differentiate one individual from another. These are the tumors which are used for experimental purposes. But, while it is true that these tumors will grow in a new host, it is not true that the cells of the new host are in all cases chemically like those of the tumor. Indeed, there is a difference which again makes it possible for the host to call into action certain defensive mechanisms against the invader, but these, under ordinary circumstances, are not strong or active enough to defeat it. There are, however, conditions which make the defensive action of the new host victorious over the inoculated tumor, and then it is destroyed. It is possible experimentally to increase the production of these defensive mechanisms.

There are certain tumors which grow in a new host of the same species for some time until, as a result of this growth, certain substances are produced by the host which cause the tumor first to stop growing and later to retrogress, become smaller, and finally to disappear. Other tumors may grow continuously without disappearing if transplanted into related strains of the same species. But if they are transplanted into different strains then they either can not grow at all or after temporary growth begin to get smaller and disappear. Thus it has been possible to demonstrate by experimental methods that there are fine chemical differences not only between different species and between different individuals of the same species, but also between different sets of families which constitute a strain, for certain chemical characters differentiate them from other strains of the same species. It has been shown, for instance, that white mice bred in Europe differ chemically from white mice bred in America, although the appearance of both strains may be identical. If we transplant an inoculable tumor of an American white mouse into a European strain, we find that such a tumor does not grow or that after a period of growth it becomes smaller, while in the American mice it does grow.

That certain chemical substances may become active to protect the new host against a transplanted tumor even if it does grow continuously can be shown by means of a second inoculation of the same kind of tumor and the same individual. We usually find that the growth of the first tumor has some inhibiting effect on the growth of the second tumor, but this inhibiting effect differs with different tumors. We must therefore assume that different tumors after transplantation into other animals of the same species contain a substance which characterizes the individual from which the tumor cells are derived more or less in the same way as the normal cells of an individual do, and that this differential substance calls forth protective mechanisms on the part of the host. Some tumors possess this differential substance to a lesser degree than others, or they are less sensitive to the defensive mechanism which is called forth in the host and they can therefore be more readily transplanted into other individuals.

As we stated before, it is possible to increase artificially the extent of this defensive reaction on the part of the host. We can accomplish this in a way similar to the one we used in the case of inoculation of bacteria. If we wish to produce a substance which is protective against a certain bacterium, we inject small quantities of dead bacterial substances or of the living bacteria after their virulence has been decreased, into the animal. Under the influence of these *vaccines*, as they are called, a certain immunity is frequently produced in the individual. If later we inject the fully virulent organism into the animal, it is often able to withstand the infection to which an animal not so treated would succumb. Now in the case of cancer the hostile agents

against which we have to protect the animal are the cancer cells taken from another individual which grow in the new host. If, instead of inoculating bacteria we inoculate normal tissue cells from another individual of the same species or tumor cells which happen not to grow in the inoculated animal, we find that after a certain time a kind of immunity is produced in that animal. If later we inoculate that animal with fully virulent tumor cells, this tumor very frequently does not grow. As we stated before, the majority of spontaneous tumors can not very well be transplanted. It is therefore comparatively easy to find a tumor which does not grow after inoculation, but which, nevertheless, forms a protective substance fatal to the growth of a virulent tumor. Now, while it is frequently possible to immunize against bacteria with dead bacteria or with certain extracts of bacteria, this is not possible in cancer immunization. Here we have to inoculate with living cells which only gradually die if transferred into the new host. Apparently a certain product of metabolism of the introduced cells, perhaps some product of oxidation, is necessary for this purpose, and such an oxidative process seems to take place only in the living cell.

How can we then interpret the mechanism which leads to the setting at work of these protective agencies? The most probable explanation is as follows: If the cell from the same species, but containing a differential chemical substance, is introduced into another individual, it attracts either directly certain wandering cells of the blood, which invade the tumor and also cause the connective tissue cells to form denser fibrous bands around the tumor, thus cutting off the nourishment from the transplanted cells, or such an effect is produced in an indirect manner. The differential chemical substance in the cells calls forth the new production of a chemical immunizing substance which circulates in the blood, or calls into action a substance which was already preformed in an animal and which it was not necessary to produce artificially. But even in the latter case an additional new formation of such an immunizing substance is added to the first substance which was preformed; these substances act upon the introduced cells, change their metabolism in a more or less injurious manner and call forth the reaction on the part of the wandering cells of the blood and of the connective tissue cells. We find, therefore, that in the case of tumors the reaction is exactly the same as with the transplanted normal tissue.

As stated before, after the so-called homoiotransplantation of tissue —a transplantation into another individual of the same species—certain wandering cells of the blood as well as the connective tissue are the principal agents in destroying the invading tissue. But just as in the case of auto-transplantation of normal tissue—a transplantation into the same individual in which it originated—no antagonistic reaction is called forth on the part of the wandering cells and connective

tissue, and no defensive reaction takes place, no chemically immunizing substance is formed against a spontaneous, autochthonous tumor. We find, therefore, that, after transplantation into another individual, cancers not rarely retrogress spontaneously. But such retrogression hardly ever occurs in a spontaneous tumor within the individual that produced it. And, moreover, not only does such a spontaneous retrogression not usually occur in spontaneous cancers, but we usually are not even able to produce experimentally a defensive mechanism such as appears when a transplantation occurs into another animal of the same species. Vaccination with either normal tissue or with tumor tissue that does not grow is of little or no avail for restricting the growth of spontaneous tumors.

We have now discussed the origin of tumors and the protective reaction in the body against tumor growth. There remains the third field upon which cancer research has shed new light. I refer to the character, conditions of growth and life of tumor cells in particular and of normal body cells in general. As has already been stated, the continuous transplantation of tumors has made very evident one fact of great biological significance, namely, the potential immortality of ordinary body cells. It had been assumed formerly that unicellular organisms like protozoa and bacteria as well as the *germ* cells—especially the ova of metazoa including the vertebrates—are potentially immortal. Provided no accident takes place, one protozoon can give origin to an endless chain of new individuals of the same species. In a similar way the germ cells of a multicellular organism, for instance, of a vertebrate, develop after fertilization into adult organisms; certain cells, however, fail to undergo the differentiation which other cells do and they form later on the germ cell—the ovum or sperm cells—in the new individual. Through fertilization they again are preserved and again give rise to a new generation of germ cells. In this way germ cells are potentially immortal, while all the other cells of the body, which, in contradistinction to germ cells, are called somatic cells, die with the individual. Now it was supposed that the death of the somatic cells was not an accident, but a necessary event distinguishing somatic cells from germ cells. This view cancer research has shown to be incorrect. We now know that most of the cells of the body are potentially tumor cells and we also know that tumor cells are potentially immortal, in the same sense as protozoa and germ cells. When we speak of "*immortality*" we must of course take into consideration the fact that periods of time which man can observe are always finite quantities and that to use the term immortality is to deal with only approximations. If then somatic cells usually die, it is due to a more or less unfavorable environment, conditions which we can not control at the present time.

There are some other interesting conclusions regarding cell life, to which cancer research has led. We have shown that it is possible

to increase and to decrease the growth energy of tumor cells at will by artificial means. If we expose tumor cells in test tubes to certain degrees of heat or cold before inoculating them into the new host, or if they are subjected to the action of certain injurious chemicals which are not sufficiently strong to kill the tumor cells, we find that the subsequent tumor growth following inoculation is very much impaired and weakened. These procedures, therefore, interfere with the action of those mechanisms which are responsible for cell multiplication. On the other hand, it is almost invariably possible to increase the virulence of tumor cells by subjecting them to mechanical stimuli, such as cutting into the tumor. Thus it comes about that tumors which recur after incomplete extirpation usually grow more rapidly than the original tumor. These observations make it very probable that the growth energy of somatic cells in general can be increased and decreased in a similar way and that the increase in growth energy in cancer cells is similar to that observed in normal cells in case of wound healing. In both cases mechanical stimuli increase growth energy.

There is a third class of observations of great biological interest that concerns the transmission of changes produced in one cell generation to another which itself has not been exposed to these changes. Thus it has been found that it is possible through the action of certain chemical substances which, for instance, may be injected into a vein and which reach the tumor only through the circulation, to produce a remarkably inhibiting effect on the growth of the transplanted tumor and in some cases even to cause its retrogression and disappearance. But we also found that through such injections the tumor cells become immunized against the action of these substances, that the effect, therefore at present is only a temporary one, and that this immunity is transferred to the next cell generation which had not been exposed to the action of the chemical. Thus in the case of somatic cells, as in the case of protozoa and bacteria, changes produced by external agencies may be transferred to at least a certain number of the following cell generations. And the same seems to take place in the case of germ cells—as in the effect of alcohol for instance—an effect transmitted to cell generations not directly exposed to the action of the poison.

If we survey what we have said of the methods and results of cancer research, one conclusion especially impresses itself upon us, namely, that there is a very close connection between cancer research and general biology. In cancer research, whether we deal with the origin of cancer, the reaction of the body against it, or the conditions favorable to its growth, we have to do in each case with the properties of cells, and these properties as seen in the cancer cell can not be understood without a constant reference to the normal cells from which it was derived. And conversely, our knowledge of the life of the normal cell,

which is essentially the problem of general biology, is broadened and deepened through cancer research. Cancer research is, in fact, a department of comparative general biology, and its fate is closely bound up with that of other biological sciences.

In closing I shall say a few words in regard to the practical application of cancer research—the prevention and treatment of the disease. We have found that there are internal and external factors concerned in the origin of cancer. Of the internal factors, heredity and the presence of certain malformations play a very prominent part in the development of cancer, unquestionably in animals and probably also in man. Of the external factors long-continued stimulation, long-continued irritation, of tissues is one of the important causative conditions. If we wish to prevent cancer we must be able to control all these factors. It is comparatively easy to do this in the case of external factors. Long-continued irritation of any sort must be avoided. Under certain conditions, for instance, it might be wise to remove all pigmented moles which are exposed to irritation. The control of the factor of heredity is more difficult. It would be one of the problems of eugenics. The difficulty, however, in applying theoretical knowledge in this field is two-fold: in the first place, living organisms are a great complex of hereditary unit factors, which are transferred from generation to generation independently of one another. This makes a selective mating very difficult. Advantageous factors are combined in the same organism with inferior ones, and it is at present almost impossible—at least in most cases—to determine which factors merit greater consideration, especially when we consider that the large majority of hereditary unit factors in the case of the higher organisms are almost unknown to us. The second difficulty in practical eugenics is the danger that methods which might be suggested for certain purposes would be contrary to that social understanding and sympathy which is the basal factor of our civilization. All we can say at present is that it might be advisable to avoid interbreeding between strains in both of which the tendency to cancer is dominant. But in the case of man even this conclusion can, at the present time, be drawn in only a tentative way.

As to the treatment: Science shows us that cancer starts as a local disturbance, and, from what we have learned, it follows that the earlier the local growth is completely eradicated the better will be the results. For this eradication surgical means should be employed in the large majority of cases. In a few selected cases some other methods might be indicated. Certain methods, depending on the application of different principles, are at present still of an entirely experimental character. How far it will be possible to develop them in the future we are not able to foretell. The investigator must follow his path quietly, guided by purely scientific aims. This will be the surest method of bringing about the greatest practical results.

INSECT MIGRATIONS AS RELATED TO THOSE OF BIRDS

BY HOWARD J. SHANNON

JAMAICA, N. Y.

MOST of us know that many great flight-ways of migratory birds have been accurately mapped out both on the European continent and on our own. But no systematic attempt has ever been made to determine the flight-lines of migratory insects. In fact, it has hardly been suggested that such lines of travel exist. Significant movements, however, observed by the writer while stationed upon the southern Long Island coast seemed to indicate that both "monarch" butterflies as well as certain dragonflies habitually travel westward along that shore, and for many autumnal days in succession, in an apparent attempt to reach the mainland and an overland southward route to the tropic zone. These studies then not only suggested the theory that *both* insects were true seasonal migrants like birds, but also that similar avenues of travel must exist in other parts of the country. This conclusion has been strikingly upheld by further explorations. For, from additional evidence gathered in the field and by means of an extensive correspondence, it now becomes possible to define some of the principal insect highways of eastern North America. These should become the basis for the study of what is virtually a new science—the bionomics of seasonal insect migrations.

One such route evidently extends along the eastern coast from the far Canadian territory to the Gulf States. For, although the Maine-coast record of a "monarch" flight is the most northerly that has been reported, many of these migrants must be directed to these natural highways soon after leaving their summer habitat in the farther north. Both this record and most others reported along the seaboard are described as "butterfly processions" faithfully following the trend of the shore whatever its local direction. For they even turn westward along the Connecticut shore of the Sound (as recently observed by the writer), and beautifully parallel their similar coastwise behavior on the southern Long Island ocean coast.

In both cases, of course, they are bound for New Jersey; and thence continue southward until the waters of Chesapeake Bay seem to cause a partial, sidewise diversion. For a great swarm, moving at a considerable elevation, was seen in the year 1886, flying southward near the headwaters at West River, Maryland, which is situated far

inland. Other scattered flights have been seen in the streets of Washington. But whether these are all isolated occurrence or bands moving from the interior remains to be discovered. However, the great "resting swarms" reported at Charleston Harbor, South Carolina, show that many of the insects either preserve, or else recover, their coastwise habit, and persist in this extensive, continental flightway,

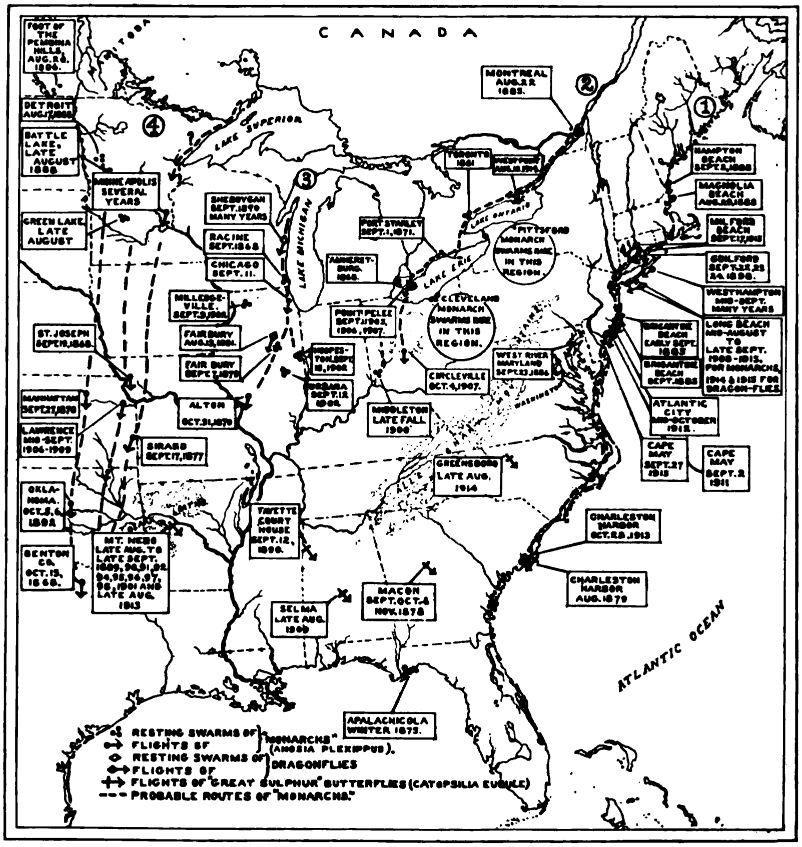

FIG. 1. AUTUMN INSECT ROUTES TO THE SOUTH. At least four great flightways are defined, (1) by the Atlantic Coast, (2) and (3) by the Great Lakes, and (4) by the West Central States. The great sulphur's inland flights in the South seem to move on a broader front except in the Ozark Mountains. (Map from the U. S. Geological Survey.)

whose further course, or possible termination, remains to be defined.

Farther west, along the northern shores of Lake Ontario and Lake Erie, another great route must exist, *even though no flights have been reported as moving in that general direction.* This flight-line was first suggested by reason of the steady, uninterrupted streams of "monarchs" reported by the bird student, Taverner, as coming down from the north, and then flying along Point Pelée, a peninsula jutting south-

ward from the northern shore of western Lake Erie. For they predicated some great, and probably specific, source of supply in the Canadian region. As a matter of fact, the territory immediately to the north was first considered the probable source of this living butterfly stream. But few, if any, records could be found in that region. What previous trail then could these myriads have followed other than the northern shores of the Lakes, as these were perfectly natural lanes of travel if the behavior already observed in the east could be duplicated here? For it would seem that, in this region too, most of the butterflies coming down from northeastern Canada would be held back and deflected by these water barriers, just as they are in Connecticut and Long Island by the Sound and ocean shore.

Only the evidence then was needed. This was readily supplied by reports of *resting swarms* at Port Stanley, Toronto, Montreal (for the route may even extend along the St. Lawrence Valley), and by the interesting description of "thousands, even hundreds of thousands of the red-winged butterflies *resting* on the shores of Lake Ontario at West Point," which was communicated to the writer by Miss Esther Steele, of Pittsford, N. Y. Moreover, this same observer reports that the butterflies never appear in any great numbers in this home region, almost directly opposite West Point, but near the southern shore, indicating that the insects rarely, if ever, cross the lake. This supposition is even further confirmed by another observer who *did* see a swarm at Cleveland, on the southern shore of Lake Erie; but who supplements his record with the statement, "they are seldom seen in this locality." Evidently, then, the "monarchs" usually avoid these great water barriers, preferring to traverse the 500 mile route already outlined, only to flood southward in the released stream which finds its outlet along Point Pelée and the contiguous islands leading to the Ohio shore, thence the flights probably continue directly southward, as shown by the record at Circleville; but after that point is reached our knowledge of their further course is lost.

Still another great route has been indicated along the west shore of Lake Michigan by reason of the swarms reported at Racine and Chicago. This flight-line, also, probably represents a released stream whose source lies still further north in some undetermined region beyond the Great Lakes. Its outlet toward the south, however, is shown by numerous reports throughout central and eastern Illinois, and, probably, by the flight still farther down country at Alton, where this tenuous thread, linking the insects of the temperate and the tropic zones, is lost.

But the wide highways of the Great Plains and the West Central States offer the most frequent reports of remarkable butterfly spectacles. In fact, they are so common in Minnesota, Iowa, Kansas, Oklahoma

and eastern Texas that they probably represent a mingling of various streams from Manitoba, the farther Canadian territory, and even from the northern shores of Lake Superior where a flight-line probably trends west only to turn south after passing the lake's extremity. The result is shown in gatherings of almost unbelievable magnitude. For here, unobstructed by barriers of lake, or ocean or mountain height, such as in other regions deflect and crowd the travelers into single-file processions, the mingled myriads move forward in broader, freer swarms that mount high, forming veritable crimson clouds; and in these impressive congregations—miles in width and streaming backward for equal distances—the crowding, ever-fluttering wings press onward toward the south, casting below them as they go perceptible shadows that move in company with the brilliant travelers in flight above the sunlit plains.

Vast aerial armies of dragonflies also advance along certain of the

TRAMEA LACERATA LIBELLULA PULCHELLA GREAT SULPHUR BUTTERFLY

FIG. 2. SOME LITTLE KNOWN MIGRANTS OF NORTH AMERICA. These two interesting dragonflies have never before been reported in migration. The great sulphur, being a Southern butterfly, does not often reach the latitude of New York in any great numbers.

highways, although the scattered and broken processions are the usual mode of travel. Moreover, by using the routes already determined as a key, further confirmations are obtained regarding the seasonal character of their migrations in the manner of birds. For not only does the common Long Island migrant, *Anax junius,* travel southward along the Jersey shore, as shown by Wolff's September observation at Cape May, but also this same species travels westward along the Connecticut shore of the Sound as shown by the writer's August and September observations.

Then, too, a report of *resting swarms,* appearing at Point Pelée (the butterfly route already defined), would seem to show that *Anax* also follows our second great highway along Lakes Erie and Ontario. In fact, still further observations by the same observer, Mr. F. M. Root, show that eight other kinds of dragons, as well, appear at the point in late summer; and, as some species are less profuse in the earlier season, they are apparently migrating to another region. Among them are

the beautiful *Libellula pulchella* and the uncommon *Tramea lacerata.* And, as both of these species (as well as *Libellula semifasciata*) have been seen by the writer in extensive autumnal migration on Long Island, it is possible that both of these species, as well, follow the two great eastern routes already defined for the "monarchs."

Indeed, when we realize that great swarms of still another species, *Æschna eremita,* have been seen in annual, September flights at Sheboygan, which is on our third great route along the shore of Lake Michigan; and that the only other autumnal migration reported in detail in this country, that of *Epiæschna heros,* took place at Fairbury, Illinois, which is the direct continuation of the same route, one discovers a remarkably interesting coincidence. It is true that other flight-ways may be defined, and also that a more or less individual wandering course may be followed down country by both insects; but it seems equally true that the great water-barriers of the ocean and the Lakes divert both migrants into the common and crowded paths already described.

Such a fundamental coincidence prepares one for further identities between these routes and the flight-lines of migratory birds. This is, indeed, the remarkably interesting fact. For not only does a great flight-way extend along the eastern coast and along Point Pelée, indicating a coincidence there, but studies at Toronto, by Fleming, suggest that a great east-and-west flight-way for birds may pass through that city, a possible parallel to our second *insect route* along the northern shores of Lake Erie and Lake Ontario.

Regarding the third route along the Michigan shore, as well as the fourth route through the West Central States, it may be said (and this statement also applies to the eastern flight-ways), that the stronger flying birds are not so easily diverted as the insects: their southward flight follows a broader, bolder course. So, although birds doubtless follow a migratory course in most, if not all, of the regions defined above, the presence of feathered travelers on the southern shores of Ontario, and thence down the Genesee Valley, as well as other records farther west, show that the higher flying birds are more independent of land-contours than the feebler insect. And, although the bird is locally diverted by food supplies, the greater numbers of the migrants seem less slavishly diverted by geographical features than the insects which, in many cases, assume a lower habit of flight.

Yet, whatever effect further data may have upon the theory of a *general* similarity of route, there is, in certain local cases, an actual identity or veritable coalescence of the vast stream of mingled life that deviously finds its flooding way to the South. For where certain physical features combine to form narrow contracted flight-ways many types of both creatures are often thrown into a common path which

affords a remarkable and convincing spectacle. Needless to say, it is along such crowded highways that further discoveries of the rarer migrants will be made.

Just such a channel is formed by Long Beach, Long Island, where it narrows between ocean and bay. For two irregular lines of dunes also traverse this land-lane, still further narrowing its course and producing a miniature valley along which both feathered and scale-winged migrants multitudinously stream. Swallows begin to sweep past even in mid-August; an occasional humming-bird (seldom noted in the literature of migration owing to the elusiveness of its long flight to Mexico) sometimes hurtles past like a shot released; the eye can hardly follow it. While the ever-present "monarchs" and the various kinds of

FIG. 3. A CONTRACTED BUT DIRECT FLIGHT-WAY. Where Long Beach narrows between ocean and bay two lines of dunes form a miniature valley. Through it both birds and insects fly side by side, "Monarchs" represented by circle-tipped arrows; dragonflies by lozenge-tipped arrows.

dragonflies conform to an aerial route along the north slopes of the seaward dunes, or in the valley, with a precision so exact that one may take his stand beforehand and find them passing directly overhead or even within reach of one's hand.

Upon broken, irregular coasts quite different behavior is seen: some insects follow one path, others another. So confused and peculiar do some of these flight-ways become, in fact, that they have led to some erroneous conclusions. Just such an instance seems revealed by a letter written in 1901 by Mr. Henry Bird, a resident of Rye on the north shore of Long Island Sound. In correspondence with a Canadian entomologist he says:

> I used to find time for a day's fishing now and then and in a row-boat would anchor a half-mile out from shore on some submerged reef. . . . And one is sure to be struck with the number of butterflies constantly coming from the Island [Long Island] to the main shore. We might expect the supply to be largest on the mainland, and that emigration would be going the other way, yet it is invariably as first stated. By far the largest number seen will be *Archippus* (''monarchs''), next *Papilios* (swallowtails), and *Colias philodice* (clouded sulphur). ''Monarchs'' seem on the wing continually during the last half of the season, and their flight over the Sound waters seems most methodical. But in this case—they are going north, mind—they fly singly.

The Canadian scientist, Mr. J. A. Moffat, then concludes the insects were gathering in the north preparatory to a southward migration.

So curious a happening seemed worthy of further investigation, particularly as insect migrations along the Sound shores had only been predicted by the writer and never definitely proved. So Milford Beach, several miles farther east than Rye, was chosen as the place of observation.

How curious was the phenomenon that presented itself almost immediately upon my arrival during a late August afternoon! For not only were "monarchs," swallowtail butterflies and dragonflies flying from over the water and toward the shore—that is, toward the northwest—but swallows, as well, were accompanying them. All alike continued inland and disappeared from sight beyond the houses and woods in that landward vicinity. So here, almost at once, was a repetition of the peculiar spectacle reported from the Rye shore fourteen years before. What is the solution?

Former Long Island studies, where swallow and insect routes coincide, gave the key to the mystery. For, upon looking far out over the water, it was seen that the swallows were traveling more nearly parallel to the shore, and seemed to be winging their way from some outjutting point of land farther east (rather than from Long Island), in an attempt to pass over the waters of the cove or bay. But on being driven southward by the brisk northwest wind they, as well as the insects, which had evidently set sail from a similar point, were forced to turn

north, directly in the face of the breeze, and to beat against it in order to reach the land at all.

Further September studies confirmed this solution. For each outjutting point of land to the east—Welch Point, Pond Point and the lesser projection of Meadow's End—sheltered its resting or hovering companies of "monarchs" and dragonflies. Each point, too, was the launching place for one or another of the insects, or of both; and, although some moved along the curve of shore, many took the more hazardous, but shorter, route over the water. Even Charles Island, midway between the two arms of the cove, held its resting migrants or

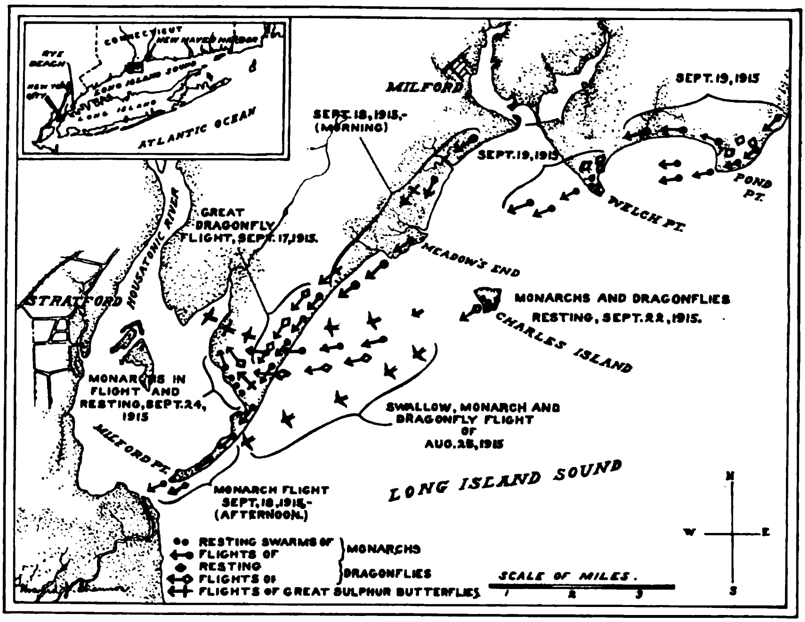

FIG. 4. CONFUSED FLIGHT-WAYS ON AN IRREGULAR COAST. On the Sound shore at Milford some insects and birds take short cuts over the water; others follow the trend of the shore. The curious northward movement around the east shore of the Housatonic is probably due to the food supplies found on that wooded shore. Occasionally both "Monarchs" and great sulphur butterflies are seen migrating southwestward through the streets of New York City.

its westward-flying units, which, owing to the small size of this land area, must have been bred upon the mainland.

The continued northward flight of both birds and insects, however, even after they have gained the Connecticut shore, seems to require a further explanation. This missing factor *may* be found in the mere presence of the Stratford marshes and the broad Housatonic waters which they border. For, although some migrants pass directly west over Milford Point, over these meadows and the Housatonic River, others (birds and insects alike) sweep northward to circle this sub-

merged area and only turn west, presumably, after passing around its perilous waters. Still the waters alone hardly seem sufficient to account for this northward diversion, as the greater reaches of the bay have been essayed without hesitation. Probably the true reason, then, is found, at least, in part, in the greater food supplies to be gathered along this wooded river-shore. For here the "monarchs" settle and feed; dragonflies hover in midair apparently gathering food, and even the swallows dip and glide as if refreshing themselves according to their usual habit.

This solution is further upheld by Dr. Bishop's careful studies in bird migration near New Haven Harbor, a quite similar body of water ten miles farther east. For here he saw repeatedly, not only swallows which are day migrants, but, also in the early morning, such nocturnal travelers as the bluebirds, robins, warblers, bobolinks and many others, nearly all of which were flying north or northwest along the eastern Harbor Shore. And, although he concludes that they were merely avoiding the wide waters, it seems more probable that they were hugging the land in order to feed after fasting through the long night journey on the wing. Moreover, so close is the parallel, in the writer's opinion, that further scrutiny should discover an insect route along this New Haven shore corresponding to our September flight-way by the Housatonic.

Still another butterfly migrant, the "great sulphur," often follows our Connecticut highways as well as the southern Eastern Shore. But this beautiful southern visitor is so fluctuant in its appearance and, at least beyond the forty-first parallel, is usually represented by so few individuals, that its summer sojourn passes almost unnoticed, and only the patient watcher of our autumn lanes of travel may catch brief, infrequent glimpses of its departing yellow wings.

In southern states it pursues regular, inland trails as well; for records recently communicated to the writer are so superior to any hitherto offered that they form a definite basis for further discovery. While resident at Mt. Nebo, Arkansas, my correspondent, Mrs. Jessie Rose Smith, was the interested observer of autumnal sulphur migrations toward the southeast for a period of ten years! It is true that the same observer has seen other southeastward flights in North Carolina and Alabama; still other students have reported similar movements in Alabama and Georgia as well. But they extend over a very brief period, and even another reference by Scudder, who quotes observations extending over a period of twenty-six years, is so vague in regard to place and direction that it has a secondary value.

But the Mt. Nebo flights, on account of the vast numbers involved, the constancy of their appearance ("we could predict their coming for days beforehand") and the uninterrupted sequence of the movements which began in late August and lasted for many weeks—

all these now familiar phenomena as observed in other insects—aroused the conviction that my correspondent must have been stationed upon some such crowded avenue of travel as has already been described in other parts of the country. Only a cursory glance at the relief map suffices to show the geographical features responsible for these recurring spectacles. For the Ozark Mountains, extending from the northeast to the southwest, lie at right angles to, and form a barrier across, the great sulphur's southeastward migration. So, held back by the hills, they are forced to turn aside and seek an egress to the warmer zone beyond these obstacles. But not until the gateway of the Arkansas Valley opens are the flocking multitudes able to move in the desired direction, and to stream past Mt. Nebo, which stands on the valley border, only to scatter again, no doubt, and move in more open order after passing the contracted flight-way of the hills.

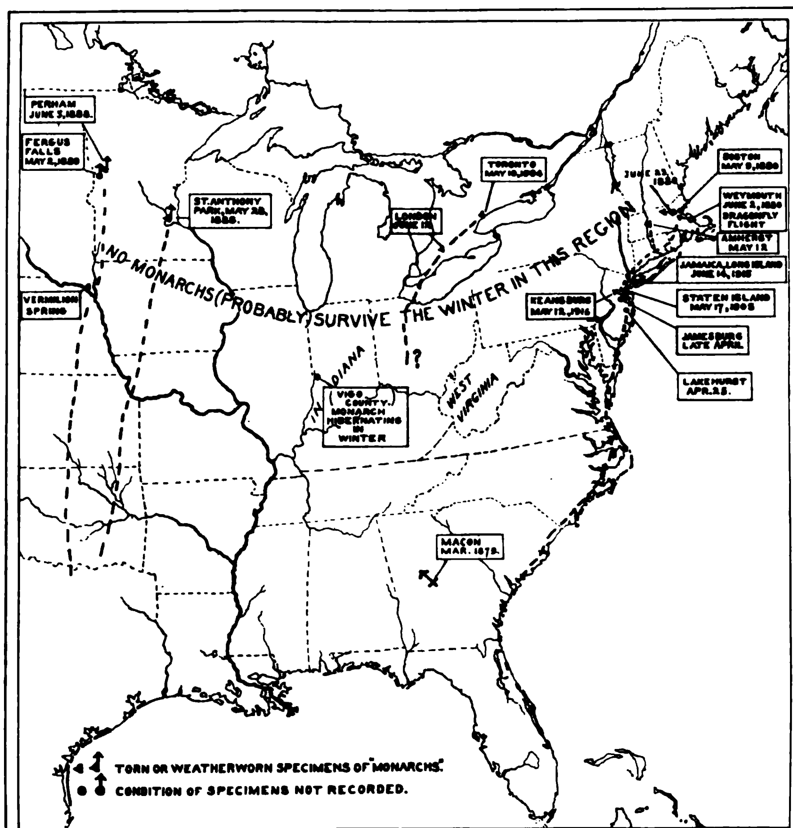

FIG. 5. EARLY SPRING APPEARANCES OF "MONARCHS" IN THE NORTH. Their distribution shows that spring routes toward the North are probably somewhat similar to the flight-lines of autumn. It is significant that, in Europe, *both butterfly and dragonfly records of Spring* are the most profuse: here, the autumn flights are the greatest. (Map from the U. S. Geological Survey.)

Unmistakable as these mountain barriers are, however, both they and the lake and ocean obstacles, already noted, seem comparatively slight disturbances when one considers the general regularity of the north and south valleys and coast-lines in North America which are the natural lanes of travel. So, in this country, true insect migration, as well as that of birds, falls into comparatively simple, unobstructed channels. In Europe, on the contrary, the east-and-west position of the great mountain ranges, as well as the ever-varying direction of the coast-line, offer peculiar difficulties to the insect flights which, therefore, become deflected and confused. These conditions alone are sufficient to account for the great varieties of direction reported for dragonfly swarms on that continent. In fact, they may also account for the apparent failure of a true interpretation there; for only the study of our more direct, but corresponding, activities on this continent has seemed to throw a considerable light upon the problem. Butterfly migrations in the old world, too, have shown such varied behavior that the idea of regular seasonal movements rests upon far less definite data than has been obtained in this country. Nevertheless, as the writer has pointed out in a previous article,[1] the recorded instances of dragonfly migrations in Europe remarkably coincide with certain flight-ways of migratory birds; so there, as well, persistent scrutiny of certain continental highways should shed an additional light upon the other insect migrants that travel there.

The more they are studied the more impressive and thought-provoking do these parallel behaviors become, until one seeks to find some complementary light which may be shed by one creature on the activities of the other. For the hitherto almost unnoted spectacle of both life-orders flooding along the same great continental highways quite naturally gives rise to thought and conjecture. Indeed, it is not impossible that the insects, being perhaps the first historic travelers along the highways, attracted the insect-eating birds, resulting in an habitual adherence to those routes, where a constant food-supply could be secured during their long flight to the south. As a matter of fact an early report of a dragonfly swarm passing over Dresden states that "starlings, blackbirds and sparrows accompanied the insects and threw themselves upon them with great eagerness." Still, excepting for hawks, kingbirds, the purple martin and, to a lesser extent, the swallows, dragonflies are not habitually chosen for food. "Monarchs," moreover, are notoriously distasteful to birds. So, as regards these two insects at least, such a theory finds little support.

Nevertheless, there may be *even other forms of insect life* which habitually use the great highways—quite different insects which *would be* desirable for food. In the writer's opinion there are considerable

[1] "Do Insects Migrate Like Birds?" *Harpers Magazine*, Sept., 1915.

evidences to uphold this contention. A large bumble bee (or bee resembling fly as yet undetermined) has been seen driving steadily westward along both the Long Island and Connecticut highways, in each case flying side by side with the "monarchs." Along the Maine coast, too, according to a communication from Mr. Norton of the Portland Natural History Society, large bumble bees have been observed flying steadily westward across the water between the offshore islands and following the same general route which "monarchs" and birds pursue.

Certain small flies, *Ilythea,* have been reported by Scudder, migrating along the New Hampshire coast in the same general direction

FIG. 6. "MONARCHS" RESTING ON THEIR MIGRATION THROUGH KANSAS. This flash-light photograph, published through the courtesy of Miss Jennie Brooks, represents a part of the Lawrence swarm of 1909 described by her in Country Life for August, 1911. In 1906 larger swarms, also described by Miss Brooks in Harpers for June, 1907, rested for the night on the same tree.

already followed by a late summer "monarch" procession. The dragonfly swarms reported by Root on Point Pelée were preceded by large flocks of "deer flies" that seemed a part of the seasonal movement; while Eimer prefaces his description of a dragonfly flight in Switzerland by saying that swarms of the "flower flies" *Eristalis tenax* and *Syrphus lavandulæ* preceded the dragonflies, which were then upon a southward, September migration. So, as great numbers of *Eristalis tenax* have been seen resting along the Long Island highway where they are rare in the earlier season, further studies may establish a definite connection between these movements and the flights of certain insect-eating birds.

It is not impossible, in fact, that such a southward trend, or diminution of the smaller insects in the farther north, may take place in sufficient measure to account for the initial movements of the dragonflies. Certainly it does not seem true in this local region. For when the

FIG. 7. "MONARCHS" MIGRATING ALONG THE CONNECTICUT SHORE. They are setting sail from Welch Point and flying over the Sound waters in order to reach the next peninsula farther to the west. Charles Island, sometimes visited by the migrants, is visible in the distance.

dragons first begin to drift south along our highways in mid-August smaller insect life is still plentiful and widespread. But the same problem confronts us in the case of many birds which begin to arrive from the north before their insect food seems to show any noticeable diminution. Yet in this we may be deceived. Certainly the insect-eating swallows are among the first to start: on the other hand, the seed and berry eaters are among the last to leave. So, whatever results more exhaustive studies may show, the simultaneous early departure of dragonflies and the birds which also prey upon insect food is still another significant coincidence.

The laws, then, which govern the smaller, seasonal migrants seem so undoubted and severe that one can not fail to perceive that more complete and far-gathered data directed toward the problem of their beginning in season and in prehistoric time may even shed an additional light upon the very origin of bird movements. For, notwithstanding the voluminous literature which has grown up about the feathered migrants and the theories of climatic change initiated by the Ice Age as responsible for their annual flux and flow, these annual adventures still remain one of the most inexplicable and marvelous manifestations of animal life. It is equally true that the application of marking and tracing methods to insects (which have long been the practise of the bird student) will now be made possible, owing to the fact that certain of the eastern routes are clearly defined, allowing the naturalist to determine the extent of the southward movement in each species, the place and manner of the winter sojourn, and, also, how many of the northward-moving migrants of spring are new generations bred in that warmer region, and how many are, in very truth, the same individual travelers which set out upon their long, southward journey in the autumn.

SUBSTANCES WITHOUT CHEMISTRY

By Dr. JOHN WADDELL

SCHOOL OF MINING, QUEEN'S UNIVERSITY

SUBSTANCES without chemistry must necessarily be elements, for, if substances form compounds with other substances, they thereby come into the realm of chemistry. The group of elements to be considered are found in the atmosphere, but their presence was not suspected until less than twenty years ago, when within a comparatively short space of time, helium, neon, argon, krypton and xenon were discovered. Of these, xenon is present only to the extent of one part in 170,000,000 of air, but argon constitutes nearly one per cent. of the atmosphere. Yet, with the exception of the chemist Cavendish, no one seems to have suspected its presence and Cavendish merely suggests the existence of some unknown gas.

In this paper there will be several digressions that may seem foreign to the subject in hand, but that are intended to help in elucidating the main topic or to explain words or phrases necessarily employed.

Two classes of elements have eluded for a longer or shorter time the researches of chemists. One class is represented by fluorine. The story is told of a man who claimed to have discovered a universal solvent and, when asked to exhibit it, replied "How can I? It is impossible to get any dish to contain it." Fluorine is somewhat of this nature. The existence of the element was suspected. The mineral fluorspar was known to contain calcium, which is the metallic part of limestone, and was suspected of containing another element similar to chlorine, which is the non-metallic part of common salt. But this element could not be got from fluorspar in a manner analogous to that by which chlorine was obtained from common salt. The element could be detached from the calcium, but only to combine with something else. When common salt is acted on with concentrated sulphuric acid (the oil of vitriol of the newspaper reporter) hydrochloric acid, a very irritating gas, is produced, and this gas with suitable chemicals gives chlorine. When fluorspar is acted on with concentrated sulphuric acid a still more irritating gas, hydrofluoric acid, is produced. Its solution in water produces, on the flesh, very distressing sores exceedingly difficult to heal. Both the gas and its solution act on glass and the etching of glass is frequently done by the use of hydrofluoric acid. But hydrofluoric acid could not be made to act on any chemical in such a way as to set free fluorine. The element entered into innumerable combinations, but did not appear alone. Thus, though chemists had consid-

ered that there must be the element and had formed a pretty fair idea of what its appearance and properties would be, still, this element, that Davy in 1813 stated to exist in fluorspar, was not isolated till, in 1886, Moissan by the use of the electric current at a low temperature, with specially resistant apparatus, obtained the element in the form of a gas whose properties were almost identical with those predicted.

Another class of elements are elusive because their presence is not suspected, and their properties are somewhat similar to those of known elements. The metal cæsium belongs to this class. In 1846, Plattner analyzed the mineral *pollux,* but could not get the constituents as found by his analysis to add up to one hundred per cent. He published his figures, however. In 1860 Bunsen and Kirchhoff discovered the element cæsium, and it turned out that Plattner's analysis needed only the correction that the mineral pollux contained cæsium, instead of what he thought was potassium. The properties of potassium and cæsium are very similar; potassium is a common metal, while cæsium is not, and it was not till the delicate methods of the spectroscope were devised that any ready means of distinguishing between the two elements was available. The five elements discovered in the air are sufficiently similar to nitrogen as not to be distinguished from it until chemists had their attention turned to the matter by experiments undertaken with an entirely different object in view.

In 1785 the Honorable Henry Cavendish, of whom the Frenchman Biot in his obituary notice remarked that he was "the richest of all scientists, and the most scientific of all the rich," made some experiments with air by passing electric sparks through it, in this way producing nitric acid and potassium nitrate (saltpeter). It is notable that this process that Cavendish first applied on the small scale and with excessive toil is now carried out on the commercial scale in Norway and Sweden, where electric power is cheap. Up till three or four years ago, however, not more than one per cent. of the world's supply of nitric acid was made in this way, since, for the most part, it was cheaper to get it from sodium nitrate or Chili saltpeter, so named from its place of origin in South America. But as 50–80 per cent. of all the more important explosives consist of nitric acid and as Germany must be pretty well shut off from South America, she must either have laid in an enormous stock of nitric acid before the war or the electric process must have since been greatly developed, unless, indeed, she has gone back to the primitive method by which saltpeter is made in the villages of India, which is very unlikely.

When Cavendish passed electric sparks through air and oxygen added as required, he found that though the volume of air diminished until it became very small, it was impossible for him to reduce it to zero; a little gas remained. He had recognized the air as containing

the gases which we now call oxygen and nitrogen, and he said that if what remained behind was not nitrogen its volume was not more than one one hundred and twentieth that of the nitrogen. He did not carry his experiments any farther, a course of action not to be wondered at when we learn that he and his assistant in carrying the investigation to this point had already kept turning the handle of the frictional electric machine for the not inconsiderable period of three weeks. Most people would count that a long enough time to keep the nose to the grindstone.

It is now possible by simply switching on an electric current to obtain the same result in a much shorter time; but, although for the last fifty years or more Cavendish's experiment could have been repeated with ease, no one thought of attempting it; and text-books in chemistry continued calmly to assert that air consists on the average of 20.96 per cent. of oxygen and 79.04 per cent. of nitrogen.

Attention was drawn to the subject owing to an investigation carried on by Lord Rayleigh, with no thought of the wonderful outcome of his work, which was started for an entirely different purpose. He set out to determine the densities of various gases, in the first place the relative densities of oxygen and hydrogen, at which he worked from time to time during ten years 1882–1892. After that he determined the density of oxygen and nitrogen and of air with a view to determining the percentage of the two gases in the atmosphere. Lord Rayleigh prepared the gases in different ways. Oxygen was prepared in three different ways, but, no matter in what way it was prepared, its density was always the same. Such was not the case with nitrogen, however. Of the nitrogen obtained from five different chemical compounds which Lord Rayleigh employed, the amount contained in the globe that he used weighed on the average 2.29900 grams, while the nitrogen obtained in three ways from the air weighed on the average 2.31049 grams. Translated into English measures, this means that approximately three pints of nitrogen got from air weighed about one seventh of a grain more than the same volume of nitrogen from the chemical compounds.

The ratio between the two weights was not far different from that between an ordinary letter, before and after the stamp is put upon it; but the actual difference in weight was only about one tenth the weight of a postage stamp. But the greatest difference in the weight of the nitrogen obtained from the different chemical compounds was not more than one seventieth the weight of a stamp, while in most of the experiments the difference was much less. It was evident then that the difference noticed between atmospheric nitrogen and what might be called chemical nitrogen could not be due to Rayleigh's errors in weighing.

Rayleigh at first inclined to the opinion that atmospheric nitrogen

was the real nitrogen and that chemical nitrogen was lighter because of the presence of some lighter substance mixed with it, but this opinion was proved to be incorrect. Then it was suggested that possibly atmospheric nitrogen was heavier, because some of the molecules contained more atoms than real nitrogen. There is pretty good proof that the molecules of nitrogen consist of two atoms; the suggestion was that atmospheric nitrogen might contain a certain percentage of molecules consisting of three or four atoms. It has been long known that electric discharges through oxygen produce an effect of this kind. Part of the oxygen is converted into ozone, which is denser, so that the same volume would have greater weight. It was proved, however, that no similar phenomenon occurs with nitrogen.

At this stage Professor Ramsay joined forces with Lord Rayleigh and, by passing nitrogen obtained from air through a red-hot tube containing magnesium, he found that, though most of the gas combined with the magnesium, a small portion did not do so, though the process was continued for ten days. This small portion was about one eighty-fourth of the whole. When chemical nitrogen was subjected to the same treatment it was entirely absorbed.

Lord Rayleigh repeated under more favorable conditions and with larger quantities of air, Cavendish's experiment of passing sparks through a mixture of air and oxygen and got a gas identical with that obtained by Ramsay. This gas is heavier than nitrogen in the ratio of ten to seven. Many experiments have been tried, but without success, to make it combine with other substances. It is inert, hence the name argon from the Greek word with that meaning. It has no chemistry—all the experiments possible with it are physical. Its inertness kept it a long time undetected. Its inertness makes it of no chemical value now that it has been found, except in so far as its inertness may affect chemical theory. Ramsay, having found argon in the air looked about for some other source. While doing so he received a letter from Miers, the mineralogist, at that time connected with the British Museum, who suggested that it might be well to examine some uraninites (varieties of pitchblende largely uranium oxide). Hillebrand, one of America's most noted analysts, had obtained a gas from uraninite which he supposed to be nitrogen. Ramsay thought it improbable that Hillebrand's methods would prepare nitrogen from any of its compounds and he reexamined one of the minerals used by Hillebrand, namely, clèvite. He did *not* find argon, but he found a gas not previously discovered on the earth, though it had been found in the luminous atmosphere of the sun, by means of the spectroscope in 1868, or about twenty-six years previously.

It may be noted that the name *helium* had been given to this element not *helion*. Nearly all the metals except the very common ones

that have been known for centuries terminate in *-um* or *-ium,* for instance, platinum, aluminium, sodium, potassium. On the other hand, several of the non-metals terminate in *-on,* for example, carbon, boron, silicon and all of the elements except helium that are similar to argon. When helium was discovered in the sun, from which it got its name, there was nothing to show that it was not a metal, and, though the Green termination *-on* would have been more suitable, it is not likely to be adopted. At the present time, the spectroscope reveals in some nebulæ, an element not found on the earth as yet, and to it the name *nebulium* is given.

Hillebrand was unfortunate in not discovering helium. The gas that he obtained responded to the tests for nitrogen, though not so rapidly as he had reason to expect with pure nitrogen. He and his assistant jokingly suggested that they might have found a new element, but as they thought it unlikely they did not pursue the investigation and so helium remained undetected for five years longer. Ramsay showed that the gas from clèveite contained 12 per cent. of nitrogen. This Hillebrand detected, but not the far larger amount of helium.

Hillebrand is not the only chemist to make a similar error. A bottle containing a heavy reddish-brown liquid was sent to Liebig for analysis. He thought that it was chloride of iodine and did not investigate it very thoroughly. Some time afterwards, in 1826, Balard discovered bromine, and Liebig realized then that his specimen was bromine, and he gave it a place in his special cabinet for storing mistakes. He was accustomed to cite it as an example of how one may miss a great discovery.

Helium is found in a number of minerals, usually in cavities of microscopic size and under a pressure of several atmospheres. In several places in Kansas, natural gas has been obtained containing more than one per cent. of helium, while in a number of other localities natural gas contains a less proportion. It is also found in some mineral waters. Experiments, carried out by Rayleigh and Ramsay, seemed to indicate that helium does not exist in the air, and Dr. Johnston Stoney gave a mathematical proof that it could not permanently remain in the air, as it is so light that the earth's attraction would not be sufficient to retain it. Whether it is produced rapidly enough to keep up the supply or that there is some unknown factor not taken into account by Stoney, the fact is that helium has been found in the atmosphere to the extent of about one volume in 185,000. Helium is only about one seventh as heavy as air and so the proportion by weight is correspondingly less. It may be added that hydrogen is even lighter than helium and even hydrogen is found to the extent of one part or more in 100,000.

The liquefaction of helium is of interest, but before taking it up it will be well to sketch the history of the liquefaction of gases. In 1823 Faraday liquefied chlorine. Other gases were liquefied by him in the

same manner. But some gases resisted liquefaction by this means, conspicuously those existing in the atmosphere. These were called permanent gases. But in 1877, Pictet and Cailletet independently succeeded in obtaining a few drops of liquid air. In 1895, processes were invented by which air could be liquefied by the gallon. Hydrogen resisted liquefaction, till Dewar, in 1898, succeeded in reducing it also to the liquid form. There was left one gas only, namely helium, unliquefied. A sufficiently low temperature was not available. But in 1908 Omnes gained the distinction of liquefying this last remaining gas and obtained a liquid that boils at 4.5 Centigrade degrees above the absolute zero of temperature, but that, so far, has not been solidified, though a temperature as low as 2.5° absolute has been reached.

A word of explanation should perhaps be given as to what is meant by absolute temperature. The difference between our coldest winter weather and hottest summer is a little more than half the difference between freezing and boiling water, which on the Centigrade thermometer is one hundred degrees. The melting point of ice is zero on the Centigrade scale, the boiling point of water is 100° C. Bright red heat is about 1,000°; furnaces for iron is 1,300–1,700°; the melting point of tungsten is 3,000°; in the electric furnace a temperature of 3,500° C. has been reached, perhaps even a higher temperature. Probably no temperature higher than 4,000° C. has been made by man, but the temperature of the sun has been estimated at 6,000° C. There is nothing to prevent us conceiving of a temperature of 10,000° or even of 100,000° in the same sense as we can conceive one hundred million dollars. While, however, we have no difficulty in attaining a temperature of seven or eight hundred degrees and can attain a much higher temperature, we not only have not reached a temperature of three hundred degrees below zero, but we are almost certain that such a temperature is impossible. Several lines of argument lead to the conclusion that at —273° C. a body would be absolutely without heat and that any lower temperature is therefore impossible. So —273° C. is called the absolute zero and helium has been cooled to —270.5° C. or 2.5° absolute without having been frozen. The difference in temperature of a room very slightly chilly and almost comfortably warm is about 2.5°.

Liquid helium is about one seventh as dense as water, which is approximately the same ratio as the gas bears to air at the ordinary temperature. When boiling the volume of gaseous helium is only eleven times that of the liquid, while steam is nearly seventeen hundred times the volume of the water from which it is produced.

In 1898, Ramsay and Travers published accounts of three other gases found in the air, *krypton* and *xenon* being heavier than argon and *neon* being lighter. The two heavier ones were got from liquid air. Liquid air is produced on the commercial scale; one of its chief uses is

as a source of oxygen. Liquid air consists mainly, of course, of nitrogen and oxygen and when it boils nitrogen volatilizes more readily than oxygen, just as alcohol distils off from water with which it is mixed. So oxygen is left behind just as water is left behind, a somewhat bluish liquid with the peculiar property of being magnetic. After the nitrogen, the oxygen volatilizes and when it has nearly gone the small quantity of liquid left is mainly argon but there is a little krypton and xenon. Ramsay and Travers used about six gallons of liquid air, Moore some time afterwards made use of the residue of a quantity of liquid air which will by most people be considered really large, namely, one hundred and twenty tons. There is one part of krypton in twenty million parts of air by volume and one part of xenon in one hundred and seventy million parts of air. Thus 120 tons of air would yield between twenty-five and thirty cubic inches of xenon and about eight times as large a volume of krypton. The latter name refers to the gas being hidden by or in the large quantity of argon which it closely resembles. There is a rare metal *lanthanum* whose name has a similar origin, since the properties of its compounds are so similar to those of another metal that it escaped notice for a considerable length of time.

The *aurora borealis* has been the object of admiration and speculation for centuries. Cavendish, whose connection with the main subject of this paper was so conspicuous, calculated the height of the aurora to be from fifty-two to seventy-one miles and probably this calculation is not far wrong. One of the theories regarding the cause of the aurora is that it is due to electrical discharge through the rarefied atmosphere and De la Rive of Geneva made a model to represent the discharge influenced by a magnet in much the same way as terrestrial magnetism affects the aurora.

When the aurora was examined by the spectroscope a very intense green line, not known to belong to any element, was found. When Ramsay was working with krypton, his assistant, Baly, examined its spectrum and noticed among a number of other lines a brilliant green one whose wave-length he measured carefully. No sooner were his results published than letters were sent to Ramsay and to the scientific press pointing out that this wave-length corresponded to that of the most important line in the spectrum of the aurora.

Neon does not call for special comment. It is lighter than air and has a spectrum not already known, perhaps receiving its name of *new* from this fact. There is one part in about 55,000 of air.

All these elements are incapable of forming compounds; they are all inert; they have no chemistry. The atomic weight of most elements is arrived at from chemical considerations, the analyses of compounds, and such like experiments. The atomic weight of these elements can not be arrived at in this way. The density as compared with hydrogen can be determined, but this alone will not fix the atomic weight, the relative

weight of the atom compared with the atom of hydrogen. One of the most important means for arriving at the number of atoms in the molecule, and in that way the atomic weight, is by determining the velocity of sound in the gas. This velocity is found in a very ingenious manner in a quantity of gas contained in a glass tube a few feet long and a small fraction of an inch in diameter. The determination of the atomic weight of an element is one of the most important investigations connected with it and for these elements physical not chemical means must be used.

Belonging to the same group of elements is still another gas, *niton,* which is not found in measurable quantity in the air. It is given off by the element radium and is sometimes called radium emanation. That it is not found in the air is not to be wondered at, since if a quantity equal to that of argon in the atmosphere were suddenly introduced into the air, it would within three months diminish to less than the quantity of xenon changing from one part in a hundred to one part in two hundred million of air. This is because niton decomposes so rapidly. In less than four days any quantity will diminish to one half what it was at the beginning of the time. One of the products of decomposition is helium, another is a substance metallic in character which itself readily disintegrates. This substance deposits on a negatively charged body brought into contact with niton, and the fact that a negative wire in the atmosphere acquires such a deposit, which may be rubbed off or dissolved by ammonia, is taken as indication of the presence in the air of an infinitesimal quantity of niton. Any further discussion of this matter would lead too far afield.

The above are all the elements *known* to belong to this group; but the Russian chemist Mendelèef, whose arrangement of the elements according to their atomic weights in series and in groups was epoch-making in the science of chemistry, suggests that there may be two other elements in the group, elements very much lighter than hydrogen, one of them almost infinitely lighter. One is the corona of the sun, the other the luminiferous ether. At present we have no means of testing Mendelèef's hypothesis.

A GLANCE AT THE ZOOLOGY OF TO-DAY

By Professor H. V. WILSON

THE UNIVERSITY OF NORTH CAROLINA

WHEN zoology is mentioned, our first thoughts turn to the different kinds of animals, to the so-called species; to the birds and insects round our homes, to the fish we have caught; to the less familiar forms of the coast, the sponges, medusæ and corals; to the beasts we have seen in zoological gardens, to the specimens exhibited in museums. This richness in variety is pleasing to most of us, and it is small wonder that the work of collecting and describing has been so actively pursued. The forms of animal life sufficiently different to be enrolled as separate species now number about half a million.

Strange as it may seem, one still at intervals hears the question, "what is the use of all these creatures?" meaning their use to us, to man. Perhaps the question is never very seriously asked to-day. For we all know a long list of organisms who, if they bring us tribute, bring a strange kind. We think of that prince of evil, the tiger; of the cobra; of parasitic worms that bore through the living flesh; of bacilli that bring disease after disease; of protozoa that cause malaria and sleeping-sickness. And we recognize that the material world is not obviously anthropocentric.

Modified, however, the question is a very rational one: what forms are inimical to us, what forms directly or indirectly useful? This question, essentially economic and hygienic, tends greatly to increase our interest in natural history, in the knowledge of the kinds of animals, and the changes of form, habit and home which they undergo during individual life. We become aware how complex are the interdependencies of organisms, how interwoven are their life-histories. We find that it is largely on such knowledge that the medical scientist and the sanitary engineer draw when they seek to combat the infectious diseases, and how vitally helpful such knowledge is to the various branches of animal industry.

These considerations show us plainly enough that biology is useful, and in making this statement we perhaps express the real nature of our knowledge in general, as something not final and comprehensive, but detailed and practical. Let us, however, not confound this aspect of the nature of knowledge with the method of science. Because the world is so ordered, and its ways so interconnected, that any or all knowledge may after a time prove useful, is no reason why we should concentrate

our attention chiefly on tasks and problems that are of immediate practical importance. On the contrary, as we survey the history of science, we see clearly that inquiries into the causes or beginnings of things, irrespective of direct utility, are of the first importance. It is these which lead to the emergence of the great general ideas, which, in their turn, light the way to the discovery of special facts that are of direct utility.

Turning from the utilitarian aspect of biology, let us take up for a moment a problem which, never new, is yet always interesting. What is the origin of all these forms that we have learned to know? What is the nature and origin of species, or, choosing the phraseology of the day, of specific differences?

In the histories of the theory of evolution we read, wondering if any of our present-day notions shall prove as untenable, that Linnæus held that species were changeless, that they were in character and number precisely as originally created. We read that somewhat later, when fossils were better known, Cuvier interpreted the present organisms and the very different ones of past geological periods as the results of separate acts of creation, each period with its living things coming to an end in some tremendous catastrophe. And that still later Louis Agassiz held the same view, while meantime he with many others paved the way for evolution by discoveries of fact, bringing to light the existence of fossil series from low forms to high, and many illustrations of the generalization embodied in our "biogenetic law" of to-day, namely, the generalization that organisms do not pursue a straight path of development from egg to final form, but commonly develop temporary peculiarities of structure constituting resemblances to lower forms.

The strong tide of evolutionary doctrine that set in with the publication of Darwin's great book in 1859 brought nothing new to what had been taught by Louis Agassiz as regards the existence of the resemblances, just alluded to, between organisms, adult, embryonic and fossil. But that the stream of living matter has been continuous from generalized type to derived form, or, as we say, from ancestral type to descendant, this is the conception that rings out the note of difference from Agassiz's teaching. Basing its argument on minor mutability that can be demonstrated and on a mass of circumstantial evidence, overpowering in its cumulative effect, evolution claimed that fundamental resemblance is not a transcendental likeness, but is due to kinship. With this conclusion we are long familiar. It has entered into the very marrow of our mental life, and everything that we learn corroborates it. The conclusion concerns us in a direct way, for the evolutionary process can not be thought of as something finished and done with. Rather do we conclude that if organisms *have* changed, they are still changing.

Granted the fact that organisms change, the question veers and we

ask in response to what do they change? Are the changes natural phenomena throughout and, as such, due to natural causes, like the up and down heaving of the earth's crust?

We are confronted to-day, as in past times, with two interpretations of nature. On the one side argument, clad in the robe of philosophy, would lead us beyond the border of the phenomenal world, seeking a reality on which all phenomena are dependent. Many tell us there is such a reality—and certainly nothing that we know contradicts them. On the other hand, the obvious world is a world of natural phenomena, which, although at bottom incomprehensible, prove on study to be orderly and predictable. That is, we learn through experience that one occurrence is associated with another, that one change brings about the next, that for every effect there is a cause.

Returning to our question, it may be said that we work and work successfully on the theory that the changes which organisms undergo are natural phenomena brought about, like any others, by natural causes. The transformation of a horde of barbarians into a modern European nation; the immunity which a race acquires against specific disease; the evolution of new breeds of dogs, horses and wheat; the spreading of a race over a wide and varied area with the consequent appearance of differences which mark off the group into geographical subgroups; the gradual loss of parts of the body, so obvious in some fossil series; the metamorphosis of a part into what is virtually a new organ; the restriction of a species to a narrow area of distribution, with the final outcome, extinction; all these we are justified in regarding as natural phenomena and as phases in the wave of change that incessantly passes over living nature.

Granted the fact of change and that it is a natural phenomenon, we become interested in the analysis of its causes. And so we begin to inquire into the origin and accentuation of the small differences which mark off a race from the parent stock. Thus we pass from the wider study of evolution to the narrower and more precise study of heredity and variation. Here the experimental method is the chief one employed, although often under the guidance of comparison and statistics.

I pass over the ideas entertained as to ways in which differences are accentuated and touch, in preference, on some of the ways in which they originate. We know very well that the body of an animal, its skin, bones, muscles, etc., made up of infinite numbers of microscopic components, the cells, responds to changes in exercise, food and environment with the production of differences which are often very well marked. But we also know that the great bulk of the obvious and familiar differences so caused are not passed on to the next generation. They are not heritable. In order to be heritable, the peculiarity must be lodged, potentially, of course, in the germ cells. These are the cells,

commonly ovum and sperm, which, leading a life aloof from the body cells, give rise to the new individual.

We may then ask, do all individual differences that are heritable originate from the very start in the germ cells, and, if so, owing to what influences? or are there subtle changes of the body cells induced by habit, food and environment, which are transmitted to and lodged in some potential form, in the germ cells? This two-sided question, it is obvious, concerns mankind in a very practical way. It has been argued warmly for many years, usually under the heading of "the inheritance of acquired characters," and still to-day, in a more clearly circumscribed shape than formerly, makes one of the most important general problems of experimental biology.

In past years it was widely held that the transmission from body to germ was a fact, in other words, that peculiarities developing for the first time in the body, not as the result of congenital constitution, but as the result of habit or outward circumstance, were transmissible to the germ. Weismann and others have shown that much of the evidence on which this conclusion rested is weak, and the result of their criticism has been in some measure to discredit the idea. There are, nevertheless, certain experiments which, while not demonstrating transmission from body to germ, do demonstrate perhaps the more important fact that the effect on the body of outward circumstance in one generation may be in some degree repeated in the bodies of the next generation, although the conditions which first induced the change are no longer operative.

Prominent among such experiments are the classic investigations of Standfuss and Fischer on European butterflies. Both Standfuss and Fischer showed for certain species that the temperature at which the pupal stage is kept, during its so-called sleep, may be made to affect very seriously the coloration of the butterfly into which it metamorphoses. In this way by employing temperatures above the normal and temperatures below the normal, butterflies are obtained very different in appearance from the type.

Standfuss having in this way obtained strongly altered individuals, bred from them, keeping the butterflies and their offspring not at the abnormal temperature which induced the change, but at the normal temperature. The great bulk of the offspring, the second generation of butterflies, proved to adhere to the usual type of the species. Nevertheless, a few examples departed from the type and resembled in varying degrees their parents.

In a similar experiment, Fischer subjected pupæ to an intermittent cold of —8° C., and in this way obtained butterflies different from the type. The offspring of these modified individuals fell into two groups, those adhering to the type and those resembling in greater or less degree the modified parents. The percentage of the latter was a considerable one.

These and numerous other experiments (such as those of Schübeler on German wheat transplanted to Norway and back again, the work of Tower on the potato beetle, that of Sumner on breeding mice at low and high temperatures, etc.) unquestionably show that the environment can exert a modifying influence on the hereditary constitution of a race, that it can originate heritable differences between organisms. They show, moreover, that it sometimes happens that a definite change is made in the body and a corresponding change in the germ cells, the change in the body of the first generation, thus showing in a measure what the heritable effect on the race will be. These important experiments mark a real advance, and it is safe to predict that they are but the precursors of many more dealing with the effect of the environment on the germ cells. At present one can not but feel that the amount of evidence is too slim to decide the question as to whether the environment first produces an effect on the body which is then transmitted to the germ cells, or whether the environment acts directly upon the germ cells, producing in them potential changes parallel to those produced in the body.

A second way in which heritable differences between organisms originate, that is, a second way in which changes in the properties of the germ cells are induced, is through amphimixis or development from two parents, wherein two sets of hereditary tendencies are intermingled.

Adopting this general method, investigators have in recent years attacked the problems of heredity and variation from two sides. On the one hand, students of experimental embryology, cross-fertilizing the egg of one species with the sperm of another, have occupied themselves in tracing the influence of the respective parents as displayed in the growth and differentiation of the hybrid germ. Sea urchins, frogs, fish are the objects which more than others have been used for such studies. This is too technical a field to admit of brief description. If there were time it would be easy to show that the connections between the study of embryology and heredity are numerous, close, and indeed fundamental to any real understanding of either.

The other great application of the method of cross-breeding to the study of heredity concerns itself not with the gradual individual development but with the reappearance of the characteristics of adult organisms in the offspring and later descendants. In this study a remarkable activity now reigns, dating from the year 1900, when certain principles of hereditary transmission, originally discovered by Mendel and published in 1865 but subsequently lost sight of, were rediscovered by several European botanists. These principles lie at the center of that collection of data, law and explanatory hypothesis which we designate Mendelism and which is the outcome of a vast amount of experimental breeding of animals and plants of many kinds.

The fundamental principles of Mendelism are no doubt familiar to

many of you. In this study attention is concentrated not upon the influence which one parent as a whole exerts upon a descendant, but upon the transmission of particular characteristics. The characteristics to which attention is paid are those in which the two parents differ sharply. They are contrasting characters like blackness and whiteness of fur in the rabbit, tallness and dwarfness of the pea vine, roughness and smoothness of coat in the guinea pig.

The conclusion of fundamental importance is that such characters do not blend in the descendants, but are passed on from generation to generation in their original distinctness. The characters, Mendelian or unit-characters as they are called, may be obvious or latent. In the familiar case of rabbit breeding, when a black and a white rabbit are bred from, the offspring are all black, but whiteness is latent in some, for if the black offspring are interbred, a certain proportion of white rabbits will appear among the grandchildren.

A point of importance is that the Mendelian characters of an ancestor behave in heredity independently of one another in such wise that new combinations may be made. Thus, if a dark, smooth guinea pig be bred to a white rough guinea pig, and the offspring be interbred, the grandchildren will be of four kinds, with respect, that is, to the qualities darkness and whiteness, smoothness and roughness (W. E. Castle). Some will be like the grandfather and some like the grandmother. But there will be other grandchildren like neither of the grandparents. In these a grandfather feature is combined with a grandmother feature, and so we get dark rough and white smooth pigs.

Thus qualities which exist apart from one another in separate organisms may be combined in one and the same individual, and new breeds be created. In such new breeds it is apparent that new qualities are not created. What is created is a new combination. This is heritable and therefore marks off the breed from others. Hybridization here, then, originates heritable differences between organisms. It may be added that the independent behavior of Mendelian characters in heredity is not necessarily equal throughout a long series of characters. In other words, characters sometimes, perhaps always, tend to reappear in groups. This important fact has been especially brought out by recent work on the heredity of the little fruit-fly, *Drosophila* (T. H. Morgan).

In a loose and general way it has always been known that new combinations of characters occur in organisms bred from two parents. In this connection Goethe's verses have often been quoted by Haeckel and others:

> From father I get my height
> And my earnestness;
> From mother dear my gladness of nature
> And delight in romancing.[1]

[1] "Vom Vater hab' ich die Statur," etc.

But Mendel's achievement was to discover order where no order had been recognized, to demonstrate that the combinations which are made are of a constant character and, moreover, are embodied in groups of grandchildren numerically proportionate to one another. We have seen that where, as in the case of the guinea pigs, two pairs of characters are considered, there will be four kinds of grandchildren. It may be added that in such a case the four kinds will be represented by the proportional numbers 3, 3, 9, 1. That is, for three of one kind, there will be three of another, nine of another and one of yet another. The larger the number of contrasting points, the greater will be the number of kinds of grandchildren. Thus Correns, one of the rediscoverers of the Mendelian principles, calculates that if the first parents differ in respect to ten points there will be more than a thousand different kinds of grandchildren.

Mendel's explanation of the phenomena that now bear his name was in the shape of an hypothesis which with various alterations, some of which are important, is in general use to-day. He conceived of each contrasting character as potentially represented in a germ cell by a particular "something." This something we speak of as a germinal factor, a unit-factor or a gene. It is thought of as a definite entity. Many, indeed, perhaps most, look on it as a material particle. Others do not make the attempt to visualize it. When the egg and sperm fuse, corresponding germinal factors are brought together in pairs, each pair of factors representing a pair of contrasting characters, blackness and whiteness of rabbit fur, for example. Thus brought together in the fertilized egg, the two factors of a pair may each produce an effect on the body of the organism into which the egg develops. Or one factor may completely dominate the other, the organism bearing the impress of that factor alone, the other lying dormant. When, for example, in the egg of the rabbit, the factors for blackness and whiteness are brought together, the factor for blackness being dominant, the egg develops into a black rabbit. But now as the germ cells are formed which will give rise to the next generation, the factors are supposed to be sorted out among them in such wise that any one germ cell does not get both, but only one, of a pair of factors. Thus, in our example, eggs will be produced having the factor for blackness only, and others the factor for whiteness only. Similarly with the sperm cells, some will have the factor for blackness, some that for whiteness. No germ cell will have both factors. This separation of the factors with the result that the germ cells produced in an individual are unlike, is the most important feature of the Mendelian hypothesis. Working on this hypothesis, it can be calculated what will be the proportionate number of individuals embodying any particular combination of characters which, through experiment, have been found to behave in Mendelian fashion. The hypothesis has received wide and striking confirmation in that the

results of the actual breeding experiments agree closely with the calculated expectations.

Such extensive use of the unit-factor hypothesis has been made that in the graphic language of the day an organism is sometimes depicted as a bundle of separate qualities, of so-called unit-characters, each the outcome in mechanical fashion of a single discrete germinal cause, which does not vary and which is self propagative. Viewed in this artificial light, biology assumes a rigid appearance far from its real nature, its task appearing twofold, to discover through cross breeding the elementary or unit characters of organisms and the laws governing their combination.

It should be said that such a conclusion is implied rather than positively stated in the writings I have in mind, and is expressly condemned by some prominent students of Mendelian heredity (T. H. Morgan). The facts of paleontology, anatomy and development demonstrate how artificial it is, for they show that every part and process varies among the individuals of any one time, and the *mode* or typical condition changes from age to age. Moreover, the parts of the body are so interconnected materially and their activities or functions are so interassociated, that to speak of the body as a group of units is misleading. It is to misuse the license that is only allowed in allegory, or in science for the purpose of facilitating description. A tiled floor is composed of pieces which can be taken apart and recombined. But an organism, Olivia for instance, is not a mosaic, for the items in her inventory, as "two lips indifferent red, two grey eyes with lids to them" are not separate and independent components. The essential features of an organism appear to be as closely associated, fully as inseparable, as are the corners, cleavage, color and lustre of a crystal, of calcite, for example. For given the right conditions, the germ cell or other regenerative mass will always produce them.

I hasten to remind you that "unit-character" in technical studies on Mendelian heredity has a definite meaning, referring to the class of differential features, which mark off the individuals of a race, or of allied races, one from the other. Such would be the color of the eye perhaps, or the fulness and curve of the lip. It is, as already said, these contrasting features in respect to which the two parents differ, which behave independently of one another and which may therefore be recombined in various ways.

The question as to the permanency of such characters in hereditary lines is interesting to all of us. There is no doubt that they are remarkably constant and persistent, but experimental breeding amply demonstrates that they are subject to the sudden changes known as mutations. It has also been demonstrated that in the course of selective breeding they undergo change (W. E. Castle). They show then, as do the many series of intergrading organisms, that the rule of heredity over living things is not absolute. Living things, in fact,

continually escape from its tyranny through modification of their germ-cell substance, modification which is brought about through interaction with the environment and through interaction with other germ-cell substances, the latter action leading not only to new combinations of the old, as in ideally strict Mendelism, but to actual change in the specific protoplasm, with the result that what are virtually new qualities emerge.

Mendelism has enormously increased the general interest in heredity, than which no subject in the whole field of science is more discussed to-day. In the midst of the discussions and admirable investigations dealing directly with this matter, it is well not to forget what heredity is. As Haeckel pointed out long ago, heredity is not a special organic function, but is only a name for the fact that the specific substance of the germ cell exhibits a set of properties substantially like those of the parent germ cell. In other words, heredity means that an egg behaves very much as the parent egg did, because, having essentially the same organization, it reacts to stimuli in essentially the same fashion. A sound knowledge of heredity is therefore dependent on a knowledge of the ways in which the many kinds of protoplasm respond to stimuli; in other words it is dependent on the general level of biological science.

In conclusion, let me say that the several aspects of zoology at which we have glanced has each an interest in itself. Otherwise there would be no hope of advance. But they fade into one another. The data overlap and the problems merge. The geographical explorer, dealing with the distribution of animals; the classifier, discovering and arranging the diagnostic features of races and species; the descriptive anatomist skillfully tracing out details of structure in finished product and embryo; the comparative morphologist, outlining embryological sketches and life histories and applying his data to questions of evolution; the analytic embryologist, unraveling physiological factors, control of which enables him to bring into being the differences which he started out to explain; the student of hereditary transmission recording the way in which characters reappear, and his other half, the student of variation, who experimentally induces new differences—these and many others are all dealing with one and the same nature, the many-sided world of living and once living things of which we form a part. The various classes of phenomena exhibited by this world of organisms, as they are mapped out and in some degree analysed, enter into and constitute biology. They form a vast and heterogeneous array, of which it may be said that the vastness will remain, will indeed steadily increase, but the heterogeneity should become less evident. For as knowledge grows and hypothesis gives way to generalization, the various aspects of the living world will no doubt arrange themselves in a more and more coherent manner, that is, we shall be more and more able to assign them to empirically learned causes, to the fundamental powers of the group of protoplasms as shown in responses to stimuli.

THE OCEANS: OUR FUTURE PASTURES

By ZONIA BABER
CHICAGO

DURING a six months' trip last year to Australia and the South Sea Islands, seventy-nine days were spent upon the desolate Pacific Ocean. Beyond the bird zone that encircles the land the infinity of lonely waterscape was relieved by two whales, a few flying-fish and a small number of albatross. Days passed without a sign of life. Such an experience might well stimulate in any one an intense desire to reclaim this terrible desert, this lifeless expanse of moving monotony. Were the sea well stocked with whale, seal, dolphin and other oceanic mammals, the interest in sea travel would be tremendously enhanced. The pleasure and entertainment of the sailors and travelers would, however, be but a small part of this beneficent reclamation.

Humanity has always been in search of "pastures green"! As land increases in value, the grazing animals are driven farther away from the centers of population to the cheaper lands or regions that are untillable. It would be considered very poor economy to graze land that would produce one hundred bushels of corn per acre. The "moving on" of the "cowboy" is his dominant attribute. Even in Australia, the continent new to European endeavor, the same story is repeated. The land near the settlements that can be cultivated with profit must produce cereals and other vegetable foods; hence the cattle and sheep are driven away into the "back blocks." Just how long this trekking of the cowboy can continue can not be stated in years. Yet it does not require a very fertile imagination to see that the time is not indefinite. When the human race takes the next step in progress and changes its goal and ideals from *things* to *people,* from the making of numerous and wonderful things to the production of strong and wonderful people, wars will be found only in the records of the savage past. Then the normal increase of humanity will make it necessary for the earth to produce its maximum of vegetation for food and clothing and the cowboy must be pushed off the land.

In our first geography we learned that the surface of the earth is three fourths water and one fourth land. This fact alone tells us that multiplying humanity must secure a great part of its food from the sea. When we can no longer afford to graze our sheep and cattle on the land, whence can we secure our beef and mutton? A survey of the

future reveals this possible meat supply in the marine mammals. If we do not soon take heed, there will be no mammals in the sea to furnish meat. Man has been so criminally or stupidly wasteful of his earthly inheritance that he has bankrupted posterity in many things on both land and sea What a story of a warfare of passive resistance the marine mammals might tell! The history of the whale, manatee, dugong, sea-cow, seal and the walrus would bring the blush of shame to the cheek of the humane reader.

The whale, the largest of living creatures, believed to be the largest animal that has ever lived on this globe, no doubt attracted the attention of the earliest people. In ninth-century European history there is record of whaling. Yet it did not become a serious matter from the standpoint of the whale until the sixteenth century. Then the French and the Spanish greatly enhanced their riches through the products of the whale that frequented the western coast of Europe. Whaling became a great European business in the seventeenth century. After the right or baleen whale was found in such great numbers by Henry Hudson in 1607 during his first voyage to Greenland and uninhabited islands of Spitzbergen, the center of whale-fishing was transferred to that region. A thousand or more were slaughtered there yearly for many years. Writing of this period in 1820, William Scoresby said that the whale-fishing "proved the most lucrative and most important branch of natural commerce which had ever been offered to the industry of man." In 1814 a Scotch whaler is reported to have secured a catch valued at $102,840. Such rewards greatly stimulated the whaling industry. "Killing the bird that lays the golden egg" has never proved to be good business. The city of Smeerenburg in Spitzbergen, that grew to a population of 20,000 people in consequence of the whaling industry, was deserted when the whales were gone.

When the Pilgrim Fathers came to this country the whale was numerous along the coast of New England and became an important industry of some of the colonists. In 1846 the United States had a fleet of 680 whaling-vessels. More than $70,000,000 was then invested in this industry. Such slaughter naturally depleted the number of whales in the Atlantic Ocean. The whalers then found their way around the Horn to reap rich harvests in the Pacific. Scammon says in his "Marine Mammals" that in the early fifties of the nineteenth century from 30,000 to 40,000 California or gray whales passed along the coast of California annually. These graceful creatures, forty or more feet in length, passed along the coast within observational distance from the shore between November and May. Large numbers of females came into the lagoons to bring forth their young. There the whalers took advantage of the affection of the mothers for their young to lead

them to their death. To-day one may travel for thousands of miles in the Pacific without sighting a single whale.

The whale has been valued by commercial people for oil extracted from the insolating blubber that envelops the animal's body, and for the baleen, or whalebone, that hangs like a curtain supported from and extending around the upper jaw. The price of these commodities has greatly fluctuated. The price of whalebone has varied from 12 cents per pound in 1821 to $6.70 per pound in 1891. In many catches in past times the blubber only was saved, as the whalebone was not considered worth the trouble in taking, and the space occupied aboard. After the discovery of kerosene, oil became so cheap that only the whalebone was saved from many a catch.

One valuable product has for the most part been overlooked. At the whaling station at Green Bay, Spitzbergen, in the year 1910 they were saving the baleen and blubber, but throwing away the meat, which looked like good beef, to the apparent delight of thousands of seagulls. It was estimated that the meat of a whale about sixty feet long, that was being flensed, was equal to that of seventy head of cattle. Is it not criminal to waste this nutritious meat when there are thousands of hungry people? Japan, thrifty and adaptable, has used this valuable food for many years. A few years ago fresh whale meat sold in their market at 7 to 15 cents per pound, according to quality. All varieties are not equally prized for food. That which can not be sent to the city markets in good condition, owing to the weather or distance, is canned at the stations. It is reported that some whale meat if properly treated can not be distinguished from good beefsteak. A considerable amount of whale meat is utilized by butchers in Norway. Whale meat is also tinned in New Zealand and sold to the native South Sea Islanders.

In spite of the cheapness of oil and the use of steel and featherbone instead of whalebone, the slaughter of the whale continues. The whaling station on the Falkland Islands, alone, reported for 1910–1911 whale product worth $2,042,500.

Other marine mammals also share the fate of the whale. The manatee and the dugong live on vegetable food and must find their pastures of seaweed, algæ, and freshwater plants near the land. This brings them near to their arch-enemy, man, and has resulted in their life histories being almost completed. The dugong, ranging from eight to fifteen feet in length, was very numerous in the tropical seas of the eastern hemisphere. It has always been highly prized for food by the natives of the warm coasts of Asia, Australia and Africa. Although the female dugong produces but one young each year, the extermination of this harmless beast was not threatened till the European appeared, spreading his deadly plague of commercialism. A few manatee may

yet be found along the coast or near the mouth of some South American rivers.

The northern sea-cow, the rytina, found at one time in the shallow waters of the Behring Sea, was exterminated by the Russian hunters by 1768. The inactive habits of this sea creature, the palatableness of its flesh, its size—from twenty to twenty-five feet in length, its fearlessness of man, and its affectionate disposition toward its kind, led to its extermination.

The walrus, another huge sea mammal, is unfortunate, from the point of view of his continuing to be an earthly inhabitant, in possessing tusks of which man can make use. It is stated in *The National Geographic Magazine,* March, 1911, that "fifteen years ago walrus tusks from Alaska sold in San Francisco amounted to 10,000. Now the sale is less than 100 per year."

The seal has always been an important, if not the most important, article of diet for all Arctic peoples who have not possessed reindeer; and it must be with a feeling of shame that we read that the Alaskan fur seal, estimated to be 4,000,000 in 1867, was reduced to 150,000 in 1911. We find comfort in the results of the deliberation of the International Fur Seal Conference in 1911 by Great Britain, Russia, Japan, and the United States. These four great powers agreed at that time to give the fur seal a form of protection in the North Pacific Ocean for fifteen years. It is hoped that the knowledge gained by these four seal-killing nations during the two months' deliberation of the Fur Seal Conference will result in the preservation of the seal for all time.

Mankind would be endowed with an abundant food pension if an international closed season could be declared for all marine mammals except the killer whale—the only one that destroys warm-blooded animals—until these valuable sea creatures could multiply in sufficient numbers to replace in part the position in the food supply now occupied by sheep and cattle. This suggestion may meet with strong opposition at first. We are always suspicious of the *new. Newness* explains the attitude of repulsion for any novel food.

Our attitude toward food is almost wholly on the emotional plane. Few people "eat to live"—"we live to eat." The query of the average person in regard to any unaccustomed food is: "Is it good?" meaning, "Does it please the taste?" He does not ask: "Is it nutritious?" "Will it feed the body?" We forget that we have learned to like all food. Some children must be taught to take milk. Persons very sensitive to taste may be slow in learning to like a new and disagreeable taste. But any one who tries can learn to like any food that is not poisonous to him.

The individual who is suspicious or afraid of new ideas, unknown people, strange animals, unusual landscapes, is called provincial. The

same term may be applied to the person who can not eat this or that wholesome article of diet. The cosmopolitan has been obliged to eat strange foods when traveling in foreign lands. By so doing he learns to like foods which he thought unpalatable when first introduced.

Hunger of sufficient intensity gives relish to any wholesome food, however strange. Explorers in the Polar regions often have been obliged to eat the flesh of the seal, walrus and whale to save their lives. We have been told that the flesh of the Australian dugong tastes like beef and is easily digested; that when salted it has the flavor of excellent bacon.

Why trouble about these strange sea monsters now? We still have plenty of grazing land! If one may generalize from past records, the sea mammals will be extinct when the grazing lands of the earth are all under cultivation. It is reported that in 1690 an inhabitant of the island of Nantucket, which has very poor soil, looking at the whales playing in the ocean said: "There is a green pasture where our children's grandchildren will go for bread." He considered the ocean from a commercial point of view. We now observe as we look at the waterscape of the world: "There is a green pasture where our children's grandchildren, far removed, will go for meat."

To the credit of humanity it can now be stated that the thinking, ethical nations are setting aside sanctuaries and preserves for birds, other animals, and plants that are liable to become extinct. One nation alone, however far-seeing and altruistic, can not conserve the marine mammals. This is an international concern and it might well be brought before the next international conference at The Hague.

WHAT'S IN A JOB?

By BENJAMIN C. GRUENBERG

SECRETARY OF THE VOCATIONAL GUIDANCE ASSOCIATION OF NEW YORK

MEN and women should rejoice in their work. Not simply because, as Solomon intimated, that is their *portion;* but because that is their *life*. The world's work occupies more than half of the waking time of the world's workers. A business man or a professional man often takes the problems of his occupation with him into the hours of "leisure," and even to his bed. But even the irresponsible workers who do not have to worry—about the work—after the whistle blows spend most of their waking hours with the job. In other words, the largest part of the life that counts, the life of which we are aware, is put in at the process by which men and women obtain the means of livelihood.

In the various demands that have been made from time to time for greater fulness of life, for life more abundant, people have asked for "shorter hours"—for more leisure—generally. Too few have directed attention to the possibilities of life within the hours of work. The artists have been looked upon as people who got their fun out of life by working all day at the sort of thing they like to do. The boy envies the professional baseball player, because the latter *plays* and gets paid for it besides! Indeed, the other fellow's job is often apt to look like play to us; but our own job, our own way of living and of making a living—that is hard work, and no fun.

The many social and civic surveys, the investigations into the industries, the "vocational" propaganda and the preachments of various schools of reformers have all helped to direct attention to the question of the individual's job. And we learn with a variety of emotions that in all except the strictly agricultural and the strictly mining communities the occupations of over ninety per cent. of the people are determined by the "finding of jobs" by boys and girls who are "willing to do anything." That is to say, more than ninety people in a hundred have no positive voice in deciding upon their "life work."

This idea, "life work," is indeed foreign to the mass of workers, though most of them are doomed to hard work for life. The expression suggests something in the nature of a *calling,* in the literal sense of that word, and it intimates some connection between the purpose of life as a whole and the character of the work. The missionary feels a calling, and he devotes himself to converting savages or saving

sinners, prepared to make every sacrifice that the service may demand. We know of physicians or nurses who look upon their work as a calling; we can even imagine a grocer who looks upon his task as in the nature of a mission—he may feel that he is sent to distribute to the multitudes their daily bread, in various kinds of cans and bags and bottles and packages, gathered by him for this purpose from the four quarters of the globe, through the intermediation of the wholesalers and jobbers. But it seems almost ridiculous to speak of the calling to paste labels on bottles of fraudulent imitations of fruit syrups, or to address envelopes for an advertising concern.

The fact is that most workers have no calling or vocation whatever, that most of them have not even any pride in their work, certainly no moral enthusiasm in connection with it. Moreover, most workers change their occupations so many times that any possible spiritual connection between the work and the wholeness of life is rudely broken. Nor do these changes correspond, in general, with stages in mental or moral development, or with stages of technical proficiency. They correspond for the most part with such stupid and irrelevant facts as these:

Boss went out of business.
We moved across the river.
The new foreman cut down the force.
Laid off—slack. Got job in biscuit factory.
They changed to piece work.
New director put in his nephew.

Well, we know what these things mean.

But now that attention has been directed to the need for a deliberate choice of a "vocation" as well as for a systematic preparation for it, the question of what kinds of jobs there are, the question of what the jobs demand and of what the jobs offer must come rapidly to the front. A given employment may be entirely satisfactory to one type of person, and a living hell to another. But, in addition to that, there are some people who are practically worthless for any job; while there are many jobs that are not worthy of any human being.

The United States Census enumerators have been sorting all of us according to a list of 9,326 "gainful occupations"—including yours and mine as gainful, although we may have different opinions on that point. Many of these occupations represent merely minute subdivisions of work in special industries, like the "collator" in a bindery, or the "puller" of basting threads. No one person, not even a reasonably small group of persons, knows all the important facts about all these occupations, except perhaps in the case of the so-called professions. But the occupations are grouped about large industrial processes, so that many of the important facts are true for whole families of occupations.

Every year thousands upon thousands of girls and boys leave school and begin to "look for work." In contemplating a proposed job, or occupation, or industry, every young person, as well as his or her parents or sponsor, should be able to consider carefully the conditions and the possibilities of the work.

First of all, it would be obviously foolish to prepare for a job that may be obsolete by the time the worker has achieved a fair degree of skill at the work. Since the introduction of power machinery into practically all industries, rapid changes in the character of the work required of the individual have been going on. An unimaginative boy who decides that he will do the same work as his father is now doing is likely to find when he gets to the working age that the job isn't there any more, or that it has become an entirely different thing from what it was in his father's time. There is no use in training children to become candle-dippers or flint-chippers, for example. Candles are used comparatively little now-a-days, and are likely to be used still less in the future; and, besides, they are practically all made by machinery. Flintlocks are used only on the stage, and there they can be just as effective without the flints; besides, not enough would be used to keep a full-sized person busy for a life time. The first question about an industry or an occupation is therefore a statistical one: is it a growing or a declining industry? Then, how many people does it employ, what are the chances of getting a start in it? And what does it mean, quantitatively, for a given locality? In parts of Russia, platinum mining offers openings for young men; but what we want to know is, what are the prospective openings for our sons and daughters near home?

However, one can change his locality, so that it might be reasonable, under certain circumstances, for a city girl to prepare herself for the business of scientific chicken expert, or for a farm lad to become a wireless operator. But we can not very well live at a time very different from that in which we happen to live. Without regard to locality, then, government statistics are to be consulted first of all. From these we can find that the business of the carriage builder is going down (and every schoolboy knows the reason why), whereas the chemical manufacture is going up; private practise of medicine is going down, whereas the number of health officers and medical inspectors and hospital surgeons and nurses is going up. We have too many lawyers, but we have not enough scientifically trained specialists on corn or cabbage or cotton or insects or bacteria.

A second important question to consider is that of possible restrictions as to race or color, for example. In the city of New York one of the public schools is in charge of a negro principal, who has under him a number of white teachers, and white as well as colored pupils. This may be interpreted to mean that there is here in the teaching business

no restriction as to color. Nevertheless, this condition is not true of the teaching business for the country as a whole, and the situation is exceptional even for the northern states.

The whole race question is closely tied up with the economic one, and there is a tendency, in mixed communities, for the races to become segregated into restricted occupations. In the cities there is practically no opportunity for a negro girl as a stenographer; on the other hand, a white man can not become a porter on a Pullman car. If a man prefers a Japanese butler and will not consider the application of an Englishman, there is the same kind of discrimination. Indeed, the discriminations shown in the economic field are not so much influenced by race prejudice as might be supposed, although this insidious type of narrow-mindedness does enter, of course. An illustration in point is the fact that the employment agents of a number of large high schools for boys reported great difficulty in placing Italian, Hebrew and negro boys with business houses. One of these agents explained the situation as follows:

"They don't want negro boys because they do not expect any to have the ability to become responsible officers in the business. They object to Italian boys on account of the outlandish names. They object to Hebrew boys because these are too ambitious."

"They" meant business men of all kinds—*including Jewish business men!* "Too ambitious" turned out, on enquiry, to mean that many of these boys are not content to remain at a routine task for a long time; that they will even leave one employer to go to another in order to learn a new line of work; that they are too impatient for promotion.

The most varied group of considerations is found in connection with the physical conditions of an occupation. The conditions of work in the packing industry were so vividly described by Upton Sinclair in "The Jungle," that many people upon reading the book resolved to become vegetarians. As the author says, he tried to reach the heart of the American people, but got no farther than the stomach. We still refuse to consider how the workers work and live.

The question of sanitary surroundings is in itself a complex one. We have all been impressed with the importance of suitable ventilation; we have not all yet learned to insist upon it. Then there is the question of temperature. One may work in a refrigerating room of a packing house and have constantly cold feet and blue fingers; or one may work before the open furnace of a steamship, or the oven of a bakery. The "top-filler" of a blast furnace used formerly to be exposed to almost unbearable heat, but in the modern plants much of his work is done by mechanical devices. Yet there is great variation in the conditions under which he now works. In some plants the top of the furnace is exposed to the wind, and a hose furnishes water for cooling off

the plates on which the men stand, so that the temperature need not be higher than that of a warm summer day; in other plants the top is enclosed so that the men are compelled to run away from the furnace at frequent intervals, to avoid complete collapse, the temperature often running up as high as 120° to 125° Fahrenheit.

Changes of temperature are also important. The glass-blower's helpers were required to run from in front of the furnace to the cold outside air, back and forth many times a day or night. Mechanical devices are gradually making this kind of exposure unnecessary, because uneconomical, to the employer. The humidity or the dryness of the air should be considered. The laundry worker exposed to a supersaturated atmosphere stands at one extreme; at the other is the worker in a flour or textile mill. And there may be much in the air besides moisture.

The dusty trades have often been described as prolific sources of a large part of our tuberculosis. There is not much choice between the dust of a cotton mill or of a grinding shop, and the dust inhaled by the breaker-boy at the coal mine—which fills the lungs so thoroughly in a few weeks that years in a clean life away from the mines can not remove it all. The employer can eliminate this dust in all industries practically, as soon as it is worth while—in a money sense. If the workers, for example, were in a position to insist upon dust-free work rooms, or if they exacted a large bonus for every cubic foot of dust that they swallowed or inhaled, it would soon be found practicable to install dust-preventing or dust-removing devices, as has already been done in many establishments. It is likely, too, that much of the dust thus saved could be converted into useful and usable commodities.

Gases and fumes are a source of annoyance, and even of injury, in many industries. In gas factories it is now economical to save all the ammonia and the other "waste" products of the coal distillation, because they have a definite commercial value. But in many clothing factories enough illuminating gas escapes from the neglected pipes and joints to be positively injurious to the workers. On the other hand, the atmosphere in a malting house or in a brewery often contains large amounts of carbon dioxide, but this is really quite harmless. The fumes from special solvents used in many paint shops and picture-frame factories are very injurious, especially to those who have not perfectly sound hearts.

The matter of light and sound deserves attention. There is as great danger from too much light and glare as there is from insufficient light and consequent eye-strain. Manufacturers have found it to their interest to standardize lighting conditions, because the output per worker has been appreciably increased as a result of such standardization. There are still, however, many workers who are exposed to a

constant flicker, or to a rapid alternation of light and dark. In some of the needle trades the needles in the machines move so rapidly that it is impossible for the operator to watch them directly for the purpose of controlling the machine; there is therefore suspended above the machine a strong electric light which shines into the eye of the worker as well as upon the needles; and she must watch the flickering reflection constantly.

The fact that most factories are noisy places is a serious one for the worker. It has been found by experiment that the constant noise produces an undesirable effect upon the nervous system of the worker, as well as upon his physical efficiency. In the presence of the noise the body tires more easily, and the monotony and rhythm of the noise have a tendency to dull the mind—very much like mother's lullaby. However, some of us are much more sensitive to these effects than others, and if you advertise for boiler-makers you will no doubt receive a number of applicants.

The posture in which the work is carried on is important. In many trades it is practically impossible to produce maximum results except in a standing position; and when you are paid by the piece, that is to be considered. In other trades various kinds of stooping and bending are required, although the scientific manager is gradually changing machinery and processes to avoid such awkward situations—it has been found more productive to avoid stooping. The modern builder does not allow his bricklayers to bend over for the brick and mortar; since Gilbreth showed that the output of the worker could be doubled by means of his special platforms and motion system, the bricklayer may hold his body erect all day long. While walking is considered to be "good exercise," there are some people who should not become letter-carriers; while sitting is often "very restful," there are many men and women who are not constitutionally able to thrive in a sedentary occupation.

People inclined to rheumatism should avoid occupations in which one must be much on a wet floor, as in certain chemical shops, or in slaughter houses. In some processes the worker must expose the skin to the action of various chemicals that are more or less injurious. Some skins are so sensitive that they find the relatively mild chemicals used in photography exceedingly irritating.

The question of accidents should not be overlooked. In some occupations daily accidents are accepted as a matter of course; in others they are exceedingly rare. In the steel industry alone there is considerable variation. If we take all the workers in that industry for whom records were available in 1910, we find that the accident rate was 245.2 per thousand workers (allowing 300 days of work to the year). Of these 2.72 per thousand resulted in permanent injuries, while 1.86 accidents were fatal. Now in the puddling process the rate for the same

year was only fifty accidents per thousand workers, and none of the accidents resulted in permanent injury or death. On the other hand, in the Bessemer steel works the accident rate was more than eight times as high—423 per thousand; and of these three resulted in permanent injury to the victims and 4.36 were fatal.

In addition to the frequency of accidents, one should consider whether the accidents result from the nature of the processes or machinery, from the worker's own carelessness, or from the carelessness of fellow workers. Many industrial accidents and diseases are avoidable through ordinary care on the part of the worker; in other industry special safety devices are available—although not always used.

The fire danger differs greatly with different occupations, as does the danger from explosions, special diseases, etc. A great deal of study has been given to this subject, especially in Germany and England; but the results of our own studies in this country are not yet available to the people most concerned, namely, those who through ignorance of the dangers annually enter upon these occupations in large numbers for no other reason than because jobs happened to be open just at the time when they happened to need jobs.

Even more important problems, but some that have received but very little consideration, are those that bear on the moral conditions of work. Take a dozen occupations with which you are acquainted, and answer for each of them this question: "Is the work justified morally, or does it rest upon the exploitation of vanity, or stupidity or ignorance or helplessness?"

In the middle ages, when the ideals of craftsmanship reached the climax of their development, men put religious zeal into the hammer blows that went into the building of a cathedral; and women worked with fervor upon the tapestries for a shrine. Such work was done for the glory of God; other work was done for the service of man. And even where it was not voluntary or enthusiastic work, the end of it was fairly clear. But to-day most industrial and commercial workers have lost the connection between the particular processes in which they are engaged and the service or glory that are to come from the work. As a result of the many fine subdivisions in the world's work, the carpenter may one day be placing wainscotting in a church, and the next day finish up the card room of a gambling club. He can not ask any questions either as to the denomination of the ultimate worshippers, or as to the legitimacy of the card games. Neither may the printer in the card factory ask whether the cards he makes are to be used for domestic euchres or for three-card monte.

Yet there are other occupations whose results contribute more directly to morally unacceptable ends. There is the making of all sorts of imitations of use and beauty: from gold bricks and counterfeit coin

to brass "jewelry" with glass gems; from fall-apart furniture to tinder-box tenements; from faked foods to murderous cure-alls; from paper shoes to shoddy. Can any person continue to manufacture and sell nostrums that are worthless—or worse—with a "ready-relief" label, and still maintain his self-respect? Can a girl design labels and wrappers and display-advertisements for this nostrum, and still maintain her self-respect? Can a chemist advise how fraud may be concealed, can a lawyer advise how the law may be evaded—and still maintain his self-respect?

Yes, yes: people want jewelry, and since they can not afford fine goods, we please them by making for them the nicest that can be had for the money that they *can* afford to spend. People want to have as handsome furniture as any they see in the stores; we give them some that *looks* just as nice as the finest—for a while. People want to be as well dressed as their employers, so we give them near-wool in stylish patterns. And all the time we shriek out loud—as loud as we can afford to—through the advertising pages and posters and sky-illuminators, urging the people to buy, buy, buy!

Very probably, people are not coerced into buying. And there seems to be *some* logic in the common attitude "They are going to spend their money anyhow, so we may as well take it." But the logic is that of the highwayman, the logic of the exploiter. There is *some* truth in the manufacturer's or the dealer's shrug which says, "It is our business to supply the demand." But the other side of the truth is that half of your efforts are devoted to creating the very demand in question. At any rate, while men will persist in getting drunk, I don't want my son to supply them the whiskey. While some men persist in losing all their savings in an attempt to get something for nothing, through a sure tip on the races, or on the stock market, or on some hopeful fool's gold-mine—I do not feel that I have a right to take their money, even though I do need it in my own business.

But most young men and women who are set at work can not find the connection between the special tasks they are performing and the ultimate service or fraud to which they contribute. There is, however, a side of the occupation that ought to be more clear. For example, is a girl asked to serve all day—at a "living" wage—surrounded by women fixed up in all the frills and fineries that the fashions permit? Or does a young chap have to carry messages that reek with foulness and corruption? In New York a state law prohibits the employment of minors as messengers during night hours; but girls may still be placed in all kinds of department stores. And in some of these stores, if a girl complains to the superintendent that the elevator man or one of the "higher" male employes has insulted her, she is disciplined by being discharged, while the gentleman in question is cautioned to be

more careful next time. Girls may still hear all sorts of things over the telephone wires.

Again, what are the temptations peculiar to the conditions of a given occupation? What are the temptations of a young musician who can find steady employment chiefly in a "music hall" or in some all-night eating place? What are the temptations of a person who is exposed to the receiving of tips? What are the temptations of an occupation that takes one away from home for long intervals, or at frequent intervals?

Yet we must guard against wholesale condemnations. There are some occupations that are absolutely impossible. But in many occupations the moral difficulties are relative: that is, one type of person can overcome temptations that another should not be exposed to at all. In the same orchestra, one musician will climb to the top in the same time that another goes to the dogs. One man may become a pawnbroker because he sees in that calling an opportunity for greater service to his poor neighbors; another sees in it not only the main chance, but he sees that as a shark does.

The complaint is now continuous that our schools fail to do what the little red school house did; that girls and boys leave school and in a few years lose all their intellectual interests. The facts can not be denied. The important question is to locate the determining factors in the situation. Again and again have investigators found that the monotonous, mechanical jobs have not only destroyed all intellectual interests, but have actually driven the ability to read from the minds of the young workers. These acquired arts of reading and writing are but superficial additions to the mental life, and can hold their place only through constant practise. Even more true is this of the habit of thinking. The nature of the work that the girls and boys are called upon to do plays a significant rôle in the mental development. Some kinds of routine work, while they do not call for mental exertion, at least permit quiet thought. Cobblers and tailors were formerly notorious as metaphysicians. But where you have to watch a machine constantly, to avoid damage to yourself or to the material, the attention is held while the operation does not add to the content of the mind. The tendency to standardize operations constantly reduces the opportunities for initiative and thought.

In other kinds of work there are many *outside* opportunities for mental enlargement. The salesman is obliged to meet human beings and to adjust himself to them at a thousand points, although what he can learn from his "line" may be very narrowly limited. In a factory for making electrical equipment or chemical products, an alert person will find suggestions for outside study, although he may be tied to a narrow round of operations within the day's work. While a cook

performs a limited number of operations in her work, there is constant opportunity for devising new combinations without limit, although hers is not usually considered a particularly intellectual occupation. Some girl who likes cooking may find in this work boundless opportunities for intellectual growth, while a hundred boys and girls become merely cooking machines.

It is a characteristic of so-called professional work that it demands constant growth. This does not mean that every lawyer or minister or teacher is constantly growing. Unfortunately it is possible for a physician to keep himself going a number of years on a few cheerful phrases and an assortment of pill-bottles; it is possible for an architect to make some sort of a living with a limited repertory of plans. But professional work is nevertheless of a kind that gives endless opportunities for thinking and learning and experimenting—in short, for growing. The same is true of many occupations that are not considered professional; that is, they may become mechanical routine, or they may be used as instruments for personal enlargement. Library work is a good example; stenography is another. In a particular library or in a particular office, the worker may be confined to routine operations indefinitely. Here we must distinguish between the vocation and the particular job. Indeed, this distinction is important in every department of economic life. For a person who has learned a special trade, one shop offers great opportunities, while another shop is a trap without an outlet.

In every occupation there must come times of great exertion that may leave one exhausted. But in some occupations the work is always pitched to the limit of endurance. In every occupation there come moments of suggestion or inspiration; but in some occupations there is stimulation every day. In some occupations the worker may set his own pace and produce—and earn—in accordance with the mood, or his energy, or his health; in others the pace is set by the machinery or by the speed of the fellow-workers, or by the character of the process, and the worker is under tension all the time.

The significance of these facts can be seen in their relation to the leisure life of the worker. One who finds his work stimulating is capable of enjoying life vigorously after working hours; one whose work is enervating becomes sodden, or seeks artificial stimulation in liquor or in dissipation. At best, the exhausted worker goes home to sleep until the next day; at worst, the drunken worker sobers up for another day's grind.

The hours of work determine the amount of leisure as well as the energy available for that leisure. But some men get more out of life with ten hours a day at their tasks than others get with only eight or six hours. The physician occasionally works twenty-four hours at

a stretch; he must frequently interrupt his sleep to attend a suffering victim of disease or accident. But he does not count his hours. A bookbinder must sometimes work twelve or fifteen hours at a stretch, or even more, two or three days a week, only to be laid off or given part time for the rest of the week; and that is a serious hardship. In many processes in the steel industry the twelve-hour day, seven days a week, was for long the accepted condition. Only within two or three years has any considerable effort been made to change the system to eight-hour shifts, seven days a week. Many occupations are seasonal, allowing many free hours during the year, but these are seldom so organized as to be of value to the workers in any sense. In the telephone service the operators in the best centrals work only six or seven hours a day, and have several interruptions for rest and relaxation; but fainting is a normal episode in the day's work.

The question of hours is closely connected with that of pay. It is possible to make a fine statistical showing of a high rate of pay per hour, where the worker makes a bare living and takes nearly all of his waking time to do it. For example, in a number of city railway systems it takes a conductor or motorman fourteen or more hours to put in ten hours of work. They get paid for the time of the actual "run" but have to wait at the barns several hours a day, to be on hand when wanted; this with systems of shifting reduce the weekly earnings to very moderate figures indeed. A tailor who works only thirty-five or forty weeks a year should receive his whole year's income during the working weeks. What sometimes looks like a high weekly wage in certain industries is subject to just this kind of reduction. Comparisons are sometimes made between weekly or hourly wages of different classes of workers without taking these facts into consideration, and the conclusions are accordingly misleading.

Another problem connected with the wage is that of mode of determining pay. In the first place, is pay made by time, or by piece, or by week, or by the year? There are many elements that enter into the determination of a system of payment, and it would not be fair to say that any one system is the best. But the system has undoubtedly a profound influence upon the attitude of the worker toward his work. The "ambulance-chasing attorney" is obviously influenced by the fact that he is a "piece worker." On the other hand, most *soldiering* is done by men who are paid by the hour or the day. An ideal system of payment has not yet been worked out, although many improvements have been suggested upon prevailing systems. Still, some plans are more advantageous for some people than others, and one should certainly think of this in considering a vocation.

There is another side to the wages question. Does the wage grow rapidly, or slowly, or not at all? In some manufacturing processes

a girl may attain the maximum wage in two months; but under such circumstances the maximum is always low. The thousands of boys and girls who leave school to go to work every year receive an initial wage averaging about $2.50.[1] The majority of those who receive considerably more than this enter occupations in which there is absolutely no training for higher efficiency and for higher income. In other words, a high initial wage means, in general, a low ultimate wage; for what is a high wage for a boy or a girl is a low wage for a man or woman, and in many industries a few years of work render the worker incapable of acquiring higher earning power.

Finally, how are the wages regulated? Does each worker come in and bargain for the best terms he can get, or are there standard schedules of pay, such as sliding scales or the like? Or is there a system of collective bargaining, such as has been recently adopted in a number of the clothing trades, and in part of the book-binding trade? What are the personal relations between the workers and the management, or employers? Can one maintain his self-respect, or must one sacrifice it in one of a hundred ways to hold his job? For example, does one have to "jolly the boss," or contribute for a present to the superintendent on special occasions? Or is there favoritism in giving out the "fat" tasks; or is there nepotism in promotions? Or would you have to suspect that each of the workers near you might be a spy?

There are many other questions that one might ask about each occupation in turn; and very few indeed of the occupations that have been studied can give a frank and satisfactory answer to each question.

Every normal girl and boy is entitled to an opportunity to acquire a vocational training that will assure a competence under decent conditions later in life—to all who are willing to work. The basis for this claim is an economic one, as well as a moral or humanitarian one. Indeed, it is a morally just claim because it is economically sound.

Nearly four fifths of the girls and boys leave school between the ages of fourteen and sixteen years, quite unprepared to do work of a kind that will support them. The only kind of work that they can find to do is the kind that is "easy to learn" but, oh, so hard to do, day after day, and year after year. For the employer has neither the facilities nor the interest to train them. In a survey made in New York City of the jobs taken by children on leaving school, it was found that in over 77 per cent. there was no training whatever; in ten per cent. there was a "chance to pick up"; in 7.5 per cent. they were put at learning one process; and in five per cent. there was "some supervision." Similar results were obtained by investigators in other cities. Children in these jobs become in a very few years fixed in their habits of work, in their

[1] Within two years, that is, since the beginning of the European War, this figure probably represents the minimum rather than the average.

habits of thought and in their outlook upon life. They have in the meanwhile become young men and women, but have not increased their earning power: the result is that we have millions of men and women incapable of earning more than children's pay.

That this situation is wicked morally, hardly any one will probably deny. That it is necessary economically, hardly any one will claim. In the first place the marvellous increase in productivity during the the past fifty years would in itself be sufficient to justify the claim for decent living conditions for all workers. But the process of improvement is continuous, and has recently received added acceleration in the development of "scientific management." In the second place, every time that outside pressure or humanitarian sentiment has wrested from employers another slice of "welfare work," the reaction showed itself in the form of increased dividends. In other words, the humane organization of an industrial or commercial enterprise *pays*. In the third place, the employers are constantly complaining that we have not enough trained workers to maintain an effective competition with foreign manufacturers; that an increased skill on the part of the workers would mean relatively larger productivity. Presumably they intend that some of the gain shall go to the workers. At any rate, the implication of the claims of these experts is that high-grade labor is more profitable than low-grade labor, even under modern capitalistic conditions which have made so much of low-grade labor attached to machines. Finally, the admission of untrained children to business and industry brings about a pernicious circle from which there is no apparent escape. It results in raising up a population of men and women incapable of earning a living wage, and doomed, in consequence, to a parasitic life on a very low plane; and this makes impossible the escape of the succeeding generations from the bondage of low standards of living.

The question then is not, "Can we afford to train children for high-grade, efficient and happy lives?"—but, "Can we afford to leave out such training?"

In looking about for means of improving the situation, we may expect much from legislation. The agitation of the labor unions, of the consumers' leagues, of the welfare workers and reformers, must bring before us the need for remedial legislation, largely in the nature of restrictions upon exploitation and the protection of the public health. Legislation of this kind should be supported at every opportunity.

But more far-reaching than legislation is an attack upon the children. They must be taught what they have a right to demand, they must be inspired to insist upon their rights.

Is it too much to ask that the jobs we are offered shall represent useful, meaningful work—that they shall help to clothe or to feed or

entertain or enlighten our fellow beings? Is it too much to ask that the work which is offered us be placed in wholesome surroundings, free from corruption of the spirit as well as of the body? Is it too much to ask that our jobs shall permit us to grow while we work, and leave us a balance of energy to play withal? Is it too much to ask that human devotion to work shall be rewarded with life as well as with the means of life?

We must demand an *organization* of work and a *distribution* of workers that will yield a maximum of satisfaction and pleasure to the workers *while at work*. We must demand that in the planning of shops and factories, in the offering of jobs and in the selection of jobs, the first consideration shall be that these things are for the men and women who are to do the work, no less than for the human beings who are to direct the work, or who are to cut the coupons.

Men and women should rejoice in their work, for that is the most of their life.

SCIENCE AND FEMINISM

BY ROBERT H. LOWIE, PH.D., AND LETA STETTER HOLLINGWORTH, PH.D.

FEMINISM demands the removal of restrictions imposed on woman's activity. Opponents of feminism seek to justify these restrictions on two grounds: (1) because of undesirable social and ethical consequences that are believed to be the necessary outcome of their removal; (2) because of the alleged unfitness of women to undertake certain forms of activity. The considerations that come under the first head lie wholly outside the field of science; for what is socially or ethically desirable depends on the individual point of view assumed, and has nothing to do with the objective determination of fact that constitutes scientific judgment. At best social science might establish what consequences would actually flow from a removal of restrictions; but social science is at present far from being able to predict future events within its domain. Science, then, can deal only with the arguments of the second order, the question whether woman is by nature debarred from successfully following pursuits open to man, and the present paper is confined exclusively to this problem. It is true that some scientists have categorically affirmed woman's inferior equipment, notably Professor Sedgwick in a much-advertised statement in the *New York Times*. In so doing they have voiced folk-lore and folk-ethics rather than science. On the other hand, avowedly feminist literature has not been free from misrepresentation of the facts. The following pages are designed to fill the long-felt want of a concise popular summary of the present state of knowledge in regard to the question of woman's supposedly natural disabilities.

The widespread conviction of woman's inability in certain directions is in large measure due to the fact that, to the knowledge of those disqualifying her, she never works and never has worked in these directions; hence the desire on her part to perform such work appears "unnatural." This point of view is, of course, not a strictly logical one; for even if woman had been uniformly debarred from work along certain lines, this might have been due to special historical causes and not at all to her native endowment. The occupation of typist-stenographer is at present practically monopolized by women, while a few decades ago the corresponding secretarial positions were uniformly filled by men. Yet we do not attribute this fact to a change in the natural fitness of the sexes to perform the required work. Nevertheless, while the argument from universal exclusion would not be rigorously demonstrative, it must be

admitted that if women were *everywhere* shut out from a number of occupations open to men, regardless of racial and social differences, this would be fair *presumptive* evidence that woman is naturally less fit to undertake the tasks in question. Before making a direct comparison of the biological and psychological status of the sexes, we will therefore try to determine woman's sphere in different forms of society.

Woman's Sphere in Different Cultures.—Unfortunately this particular problem has been obscured by feminists as much as by any of their opponents. Among many adherents of woman's cause, there is a firm belief that all mankind at one time passed through a stage of society called "the matriarchate," in which women ruled supreme and men played the second fiddle. Only at a later period men are supposed to have risen to the ascendancy, hence, it is argued, the inferior position of woman in modern times is not rooted in sexual differences, but results from man's social position of vantage.

A correct conclusion should never be bolstered up by erroneous reasoning; and in the present instance the argument is scientifically worthless, because no satisfactory evidence of a general matriarchate condition has ever been advanced. The following are the facts: A great many primitive peoples of the world reckon kinship either exclusively through the mother or exclusively through the father; the matrilineal kin group being commonly called (by American ethnologists) a "clan," the patrilineal kin group a "gens." However, there are also not a few tribes without either clans or gentes; and in many cases there is not a shred of evidence for the view that the gentes were ever preceded by a clan system. Thus, it can not be regarded as a fact that the matrilineal clan represents a once universal stage of social development. But, even if it did, this would be very different from asserting a matriarchal stage. To trace descent through the mother is one thing; to yield social prerogatives to woman is a very different thing. Thus, we find a well-developed system of maternal descent among the coastal tribes of British Columbia, but though a man inherits his mother's clan name and his maternal uncle's property, women play an altogether subordinate part in the tribal life. It is true that instances may be cited on the other side: among the Iroquois, in particular, there is not only descent through the mother, but something approaching a matriarchate, *i. e.*, a far-reaching influence of women on the conduct of social and political affairs. Such examples, however, are decidedly rare; as a rule, whether in North America, Australia or other areas, the matrilineal system is *not* coupled with matriarchal privileges.

The really important question is, what has been the field of woman's activity in different times and regions? The care of the children devolves on her from biological necessity. This task and her inferior muscular powers would keep her from war and the chase. Are there any further restrictions which the consensus of human societies has de-

clared as inherent in sex? The answer of ethnology seems to be a clearly negative one. In every tribe there is indeed a division of labor between the sexes over and above what seems determined by the demands of infants and the differences in physical strength. But the types of activity associated with woman and man differ from tribe to tribe. Among the Hopi all the weaving was done by men, while among the Navajo, who are supposed to have learned the art from the Hopi, its practise fell to the woman's share. In North America the shaping of earthenware vessels seems to be a feminine pursuit; but in some sections of Africa men function as potters. It is not *a priori* obvious why the tanning of skins should be executed by women among the Redskins; why agriculture is the work of men among the Pueblo and of women among the Iroquois Indians; why the realistic painting of Plains Indian robes should be done by men; while the geometrical painting of rawhide bags is a prerogative of woman.

Without going into further detail, we may safely state that almost everywhere woman's contribution to culture is an important one. So far from being confined to the activities currently associated with the household, she often plays a most important part in the economic life, and practises indispensable tribal arts and industries. It is indeed true that these activities do not involve so sharp a separation from the household work as would result in modern conditions. An African agriculturist can ply her hoe with a child on her back; an Indian tanner may scrape and smoke hides, plait baskets and embroider quillwork in the intervals of domestic duties. But for our present purpose this fact is irrelevant. We are concerned with determining whether there are fields of work that woman should be debarred from for reasons of natural unfitness. What we actually find is that the work assigned to woman (beyond the obvious biological duties) is a matter of social custom, due doubtless in each particular case to specific historical causes. Ethnological evidence does not permit us to say that it is natural for women to exercise political functions as among the Iroquois, or to be rigidly excluded from tribal activity as in Melanesia and Australia; it does not prove that women are naturally more or less fit to be potters, weavers, tanners, gardeners, artists, poets or what not. It merely indicates in different communities considerable differences in the apportionment of modes of employment between the sexes. It does not justify the theory that the apportionment that had developed in our own civilization until the most recent times represents the one natural division of labor. If that conventional restriction of feminine activity is a natural one, proof must be given on other than ethnological grounds.

Biological Status.—Let us then turn to a direct comparison of woman's and man's biological and psychological status. Is woman by virtue of her organization anatomically and mentally in any way an inferior being?

As late as 1884, Paul Albrechts attempted to establish the "greater bestiality of woman from an anatomical point of view" by showing that in no less than nine points she approached more nearly to "our wild ancestors." In the tenth edition of Ploss and Bartels' "Das Weib"[1] Professor Paul Bartels exposes the absurdity of this view (p. 6). Of Albrechts's nine propositions, four are either erroneous or doubtful, one irrelevant, the remainder of no importance for the problem at issue. "The entire question," concludes Professor Bartels, "is wrongly put; it is, in my opinion, idle to debate, which of the two sexes of a single class of mammals is of 'lower' rank; moreover, we could, if we so desired, urge the more powerful masticatory apparatus of man, or, following O. Schultze, his larger face in proof of the contrary assertion." Professor Schultze, who emphasizes the relatively childlike character of woman, is indeed careful to refrain from drawing the inference that for this reason man is anatomically superior. It is true that woman, like the new-born infant, has a relatively long trunk, short legs and a rather large head, but, as Schultze points out, any argument for inferiority on such grounds proves a two-edged sword: for, by virtue of his longer extremities and smaller head, man approaches the ape type in greater measure than does his mate.[2] Schultze, who is by no means an adherent of feminism, arrives at the general conclusion that man and woman are fundamentally different organisms, but of equal biological perfection. This is likewise Bartels's summing up of the situation.[3] The fact that these authors nevertheless contend for a differentiation of function because of the anatomical differences need not concern us in this connection.

One point that continues to be urged with much insistency and much lack of intelligence is the inferior size of woman's brain, for in the popular mind intellect and brain weight are closely associated. It is therefore worth while to consider this subject at somewhat greater length.

It is true that the *absolute* weight of man's brain is greater than woman's in every people among whom the comparison has been made. Thus, a large series of English brains shows an average of 1325 g. for the males and of 1,183 for the females; while in a Saxon series male and female brains average 1,355 and 1,223, respectively. A corresponding result is obtained when the brains are compared for cubic capacity rather than for weight: a Bavarian series of 100 male, and an equal number of female, brains yielded average capacities of 1,503 and 1,335 c.c., respectively. In short, the *absolute* size of man's brain does exceed that of woman.[4]

However, it is equally true that the absolute size of an elephant's or

1 Leipzig, 1913.

2 "Das Weib in anthropologischer Betrachtung," Würzburg, 1906, p. 20 f.

3 *Op. cit.*, p. 55.

4 See Bartels, *op. cit.*, pp. 34–35.

whale's brain considerably exceeds that of the male human brain, the weight of the elephant's being from 4,100 to 4,800 g., and that of the whale from 1,900 to 2,800 g. Hence it would seem rash to attach much importance to absolute brain size in comparing male and female intelligence. This skepticism is supported by the individual differences in the brain weight of men as compared with concomitant individual differences in intellect. While it is true that distinguished men often have a brain of more than average size, this is by no means uniformly the case. Noted scientists have been known to fall appreciably below the mean, while persons of moderate ability have turned out to possess enormous brains. In Waldeyer's series the two extremes, 900 and 2,000 g., were found to belong to two mentally quite normal men.

Abandoning the comparison on this basis, we may investigate the *relative* brain weights, *i. e.*, the weight of the brain in relation to the total weight of the body. But here we get the result that woman has a relatively larger brain than man. While the ratio of male and female body weight is as 100 : 83, the brain weights stand in the ratio of 100 : 90. Schultze has calculated the proportion of brain and body weight in man and woman according to the determination of various scholars, and finds a uniform difference in favor of woman. Thus, Schwalbe sets man's average brain weight at 1,375 g., woman's at 1,245 g.; and man's total weight at 65,000 g., and woman's at 55,000 g. This yields a proportion of 1 : 47.47 for man and of 1 : 44.17 for woman.

Can we legitimately infer from these undoubted facts that woman is intellectually superior to man? Hardly, if we draw upon corresponding data from the animal kingdom at large. For then we discover that the human species as a whole is surpassed by the rat, that the mole occupies an intermediate position between man and woman, and that the elephant has a very small relative brain weight. The comparison on this basis is not wholly worthless, for we find that of equally heavy animals the biologically higher type has a relatively heavier brain, and that of two closely related and presumably equally intelligent animals (such as the lion and the cat) the smaller invariably has a greater relative brain weight. It has been suggested with some plausibility that woman's superior relative brain weight is an illustration of the general rule last-mentioned.

What conclusion, then, can be drawn from the facts of brain weight as to the superior mental organization of either sex? Obviously, the only sane inference is that such superiority on either side is quite unproved. Some correlation between brain and intelligence undoubtedly exists; but not in the sense that the size of the brain fully determines intelligence. Bartels's summing up of the situation seems the only warrantable one: so far as we can infer anything from the brain weight of man and woman there is presumably equality of mental ability.[5]

[5] Plotz-Bartels, *op. cit.*, p. 48.

The Psychological Data.—Let us now turn to the argument from psychology. Formerly it was held by men of science and laymen alike that women were mentally inferior to men, on the average; that if the mental abilities of all men and of all women could be averaged separately the result would show a great advantage in favor of men. Exact experiment and class-room experience, however, have led many men of science to abandon the hypothesis that women are on the average mentally inferior to men.

It should be noted that the laboratory experiments purporting to establish sex differences are frequently without bearing on the question of differences in the higher mental processes, and that perfect correlation between efficiency in laboratory tests and efficiency in normal pursuits has not been established. Indeed, Heymans, a careful and conscientious thinker, in his monograph on feminine psychology[6] falls back almost entirely on the direct estimates of university professors as to their men and women students. To be sure, his informants, on the whole, support the time-honored view that women are more industrious, but lack creative power and independence of thought, yet, as Heymans himself recognizes, these judgments may have been largely affected by the judges' initial bias. That this is indeed so is suggested by a comparison of equally offhand judgments by various scholars not cited by Heymans. Thus, Paul Bartels[7] is convinced that the average woman is as competent as the average man, whether at the chessboard or in politics, in science or at the stock exchange, or wherever else in life activity depends predominantly on the intellect. Her great inferiority appears, according to this writer, where efficiency is the result of a well-developed personality: she fails as a leader of crowds or captain of a ship, in poetry, as a physician, as a teacher and leader of boys, etc. In striking contrast to this view stands that of Forel, who considers women and men on a par emotionally, men superior intellectually, and women superior in point of volition. In the face of such disagreement, we may well doubt whether the time has come for a definite statement as to the psychological equipment of woman as compared to man. To revert to the method employed by Heymans, it is interesting to note that a number of American professors who have answered Professor Sedgwick's article in the *New York Times* find no inferiority on the part of their female students. The general change of attitude noticeable on this subject in academic circles gives at least presumptive evidence to the effect that the older opinion was a doctrine of more or less rationalized folk-belief without adequate foundation in fact.

Nevertheless, it is true that woman's intellectual achievement as recorded in history has been inferior, and even scholars who admit the

6 "Die Psychologie der Frau."

7 *L. c.*, p. 48.

equality of man's and woman's intellectual endowment now seek to explain this fact on the score of alleged greater male variability.

About a century ago the anatomist Meckel in his "Manual of Descriptive and Pathological Anatomy" concluded on pathological grounds that the human female was more variable than the human male; and he thought that, "since woman is the inferior animal, and variation a sign of inferiority, the conclusion is justified." Later, when variability came to be regarded as a sign of superiority and as a trait affording the greatest hope for progress, anatomists and naturalists arrived at the conclusion that the male is more variable. Men of science who had gone so far as to take the stand that women are *on the average* equally able with men, now inferred from the alleged greater anatomical variability of males that males must also be mentally more variable, and declared women's failure in intellectual achievement to be due to this fact.

Unfortunately for this theory of inherently greater male variability, however, there appears to be no support for it in precise data. Karl Pearson, in his "Variation in Man and Woman" (1897), showed that when anatomical measurements of adults are treated with proper statistical precision, "there is no evidence of greater male variability, but rather of a slightly greater female variability." More recently Montague and Hollingworth[8] have shown from a study of 2,000 newborn infants that there is no demonstrable difference in variability between the sexes at birth. As for mental variability, the precise data at present available have been summed up by Leta S. Hollingworth[9] in a critique recently published. No proof of greater male variability in mental traits can be found in the scant and inconclusive data available on the subject. The theory exists, but the evidence does not.

Yet it is possible to admit equal endowment and equal variability and still to regard as impossible equal achievement on the part of woman. The traditions and tales of savages are replete with the primitive superstitions that center round the functional periodicity of women. And the literature of the nineteenth and twentieth centuries is replete with dogmatic assertions respecting the same subject. A long and patient search through this literature brings to light a veritable mass of conflicting statements by men of science, misogynists, practitioners, and general writers as to the dire effects of periodicity on the mental and physical life of women; but the search reveals scarcely a single fact upon which the earnest, but critical, seeker after truth can lay his hand and say, "Here is a point established." Men eminent in their professions are found announcing the most dogmatic and contradictory notions. Unfortunately for the scientifically minded, they fail, for the most part, to give any hint of the methods by which they arrive at their

[8] Helen Montague and Leta S. Hollingworth, "The Comparative Variability of the Sexes at Birth," *Amer. Jour. of Sociology*, 1914.

[9] Leta S. Hollingworth, "Variability as Related to Sex Differences in Achievement," *Amer. Jour. Sociology*, 1914.

conclusions, usually prefacing their remarks merely with the convenient phrase, "It is very well known." It is certain, at all events, that they did not arrive at their conclusions by introspection; and it scarcely seems likely that much trustworthy information will be accessible on this subject till women have prosecuted their own researches into it. As in the case of variability, the most recent and thorough study, in fact the only precise study, made as to the effects of school work on the periodic function fails utterly to confirm theory. A. E. Arnold,[10] who made the study, announces as his conclusion, after closely following up the records of over 1,000 women over eighteen years of age during two years of college work, that "all effects thus far observed have been in the direction of improvement."

It is amusing to note how every sex difference that has been discovered or alleged has been interpreted to show the superiority of males. When students of institutional statistics discovered that there are more males among inmates of idiot asylums, and supposed this to mean that there must be more males than females among the feeble-minded, this apparently unfavorable fact was at once interpreted as confirmatory evidence of greater male variability; and as such it became immediately favorable to the theory of male superiority. Had it been found that there were more females among inmates of idiot asylums, how easily it could have been used as evidence of the general inferior quality of female mind.

Conclusion.—We may now sum up the argument as follows: The restrictions of woman's sphere on the ground that certain occupations are not *natural* for woman because they are not customary feminine occupations in modern civilization, rests on sheer ignorance of history and ethnology, which reveal a very considerable range of activity under varying social conditions. Anatomically, it may definitely be stated that both sexes occupy the same level. A comparison of male and female brains fails to establish the superiority of either sex. With the removal of folk-psychological prejudices, and with the advance of psychological experiment, a corresponding conclusion is gaining ground as to the average mental equipment. And while the scarcity of female geniuses, and corresponding infrequency of epoch-making achievement, has been attributed to greater male variability, a sex difference in variability has never been scientifically demonstrated. Finally, the hackneyed objection, that women are unable to perform work with male efficiency because of their catamenial function, appears as pure dogma. The verdict of present-day science is thus an uncompromisingly negative one: no rational grounds have yet been established that should lead to artificial limitation of woman's activity on the ground of inferior efficiency.

[10] "The Effects of School Work on Menstruation," *Amer. Phys. Ed. Rev.*, 1914.

MYSTICISM IN WAR

BY ELSIE CLEWS PARSONS

TO some of us not least among the pungencies, or if you prefer exasperations, of the European war is the spectacle of its leaders appealing to the gods,[1] or rendering them thanks for the victories put down to their credit. The Czar holds up the sacred *ikon* to be gazed upon by his kneeling, worshipful troops. The Kaiser makes speeches and issues proclamations about the motives and purposes of the God of the Fatherland and of his royal house. Even the British recruit is asked to enter into partnership with God.

But Czar and Kaiser are only true to their kingly parts. As for the British recruit, his cooperation might be considered an instance of delegated sovereignty. But all of his sacerdotal sovereignty the English King has not delegated to his subjects. Some of his sacred war functions George IV himself retains. Has he not vowed not to touch a drop of liquor during the war? A vow is of course a religious act. We recall at once in this connection the vow and sacrifice of Jephtha, the leader of the Hebrew army, and we recall the sacrifice of Iphigenia by her royal father.

Agamemnon in this instance performed a very special act of sacrifice—the circumstances were so contrary—but it was the usual thing for a Greek king whenever he set out on a campaign to sacrifice to deity. Fire from the altar of Zeus was carried in the vanguard of the Spartan army until the army reached the frontier. There the King sacrificed again.

In cultures even more primitive than ours or than the Greek the supernatural rôle of chieftancy in time of war may also be seen. Among the Melanesian tribes of New Guinea there are certain chiefs whose principal function is making war magic. The *paiha* chief of the Roro-speaking tribes carries charms of leaves and bark and pieces of broken weapons into battle, and before the warriors set out he doctors them. Approaching a hostile village, the Mekeo *faia* chief spits on a plant called *ofe* and with it in his hand delivers in the air an overhand blow, striking downward in the direction of the enemy's village. He passes the plant under his right leg and again strikes downward, murmuring spells the while to cause the enemy to sleep heavily. Just before reaching the village he crouches on the ground, blocking his ears with his fingers to

[1] I use the plural advisedly—the deity whose building is bombarded can hardly be the same whose aid is invoked to destroy it.

induce deafness in the enemy. Then, as the rush is made, each warrior jumps over the crouching *faia* chief.[2]

Not only are some of the methods of war magical, not only are war leaders the magicians *par excellence* of their people, the heads of the church; but the very motives and impulses of war arise in part from the same kind of association with which magic is likewise concerned, at least, what is called sympathetic magic. Sympathetic magic is due to a sense of participation. Things that have been in contact affect each other both during and after the contact, and like affects like, these are the two leading principles of sympathetic magic. It is an analogous principle of association, an analogous sense of participation which prompts the family vendetta, the tribal feud, the wars of hamlets or hordes and, may I add, the wars of nations or races. The individual's sense of participation in his group, in his family, tribe or nation, is disturbed when any other fraction of the group is disturbed. He himself feels injured when the group in any part suffers injury. He therefore proceeds to protect his nation, his people, his home, *i. e.,* himself by retaliation upon the injurious group or *any part of it.* This "family feeling" or *esprit de corps,* this sense of patriotism, is a purely subjective feeling, and, like all such feelings, it is unconcerned by logical contradictions, it is untested by objective reality—it is, in short, highly mystical.

What is the difference between this kind of mysticism and mysticism ordinarily speaking, between uncritical group feeling and piety? Piety too is non-logical, subjective, craving union, but the union it desires is not with humans, its sense of participation is with deity; so long as that sense is intact, piety is unconcerned about human relations. Piety is unconcerned about human relations in themselves, but, as the sense of union with deity is immensely strengthened by the sense of common worship, the pious are in fact concerned about the body of the faithful. What that body is to consist of is a matter of circumstance. Consider Christianity. Owing to the circumstances of its genesis, Christianity was dissociated from social groups. It was adrift, so to speak, in society. It was lonely. It developed the dogma of the brotherhood of man, quite as mystical a dogma as nationality or any other principle of kinship. But, after two or three centuries, when Christianity was adopted as a state religion, the Christian's gregarious instinct was satisfied in another way; his sense of participation with mankind became superfluous; it began to atrophy. One with his church-state, the Christian rose up against heretic and pagan, his pristine brethren. Warfare with the enemies of the Christian Church but intensified his sense of participation with the Father of Mankind. The Crusades and the In-

[2] May I suggest that the stimulus given before a charge by magic corresponds to the encouraging shibboleth words of a commander in modern war or to the "dope" allotted, according to Jane Addams and Gilbert Murray, before a cruel bayonet charge?

quisition gave Christians a full measure of the sense of union with God, probably the fullest measure they were collectively to have.

For then, in course of time, came the movement historians call nationalism, a movement which subordinated church to state, the faithful to the patriotic, a movement which made of God at most a national hero. To illustrate this subservience of the godhead I can not do better than cite the colloquy between Shatov and Stavrogin in Dostoevsky's novel, "The Dispossessed," and let me cite it at length, for not only does it illustrate the rôle of the gods in nationality, it expresses extremely well that more fundamental mysticism of nationality which, we hold, is the source of international war. Shatov is speaking:

"Nations are built up and moved by another force [a force other than science and reason] which sways and dominates them, the origin of which is unknown and inexplicable: that force is the force of an insatiable desire to go on to the end, though at the same time it denies that end. *It is the force of the persistent assertion of one's own experience,*[8] and a denial of death . . . the seeking of God, as I call it. . . . The object of every national movement in every people and at every period of its existence is only the seeking for its god, who must be its own god, and the faith in Him as the only true god. God is the synthetic personality of the whole people, taken from its beginning to its end." . . . "You reduce God to a simple attribute of nationality," exclaims Stavrogin. "I reduce God to the attribute of nationality?" cries Shatov. "On the contrary, I raise the people to God. And has it ever been otherwise? The people is the body of God. Every people is only a people so long as it has its own god and excludes all other gods on earth irreconcilably. . . . If a great people does not believe that the truth is only to be found in itself alone (in itself alone and exclusively); if it does not believe that it alone is fit and destined to raise up and save all the rest by its truth, it would at once sink into being—not a great people.

A striking portrait, is it not, of the patriotic Christian, the Christian national?

But why is it, I may be asked, that despite Christianity's subjection to nationalism, despite its own peculiarly bloody history, there has persisted in Christendom a belief in the sanctity of human life, a conviction potent enough at times to make for large bodies of heretics like the Lollards, the Anabaptists, or the Quakers, a conviction that is even today a thorn in the flesh of the unmitigated militarist nationalist?

This outcropping conviction, this stubborn feeling, the Christian pacifist likes to date back to the early years of Christianity; but it is, I suspect, pre-Christian, nay prehistoric. It is akin, I suggest, to the horror of blood pollution felt by primitive peoples. It expresses the same aversion to killing another human being that taboos on the savage homicide betray. After a Pima killed an Apache he had to fast for sixteen days, touching neither meat nor salt, nor looking at a fire blaze, nor speaking to a human being. Were he to touch his head or his face with his fingers, his hair would turn white and his face wrinkle. Unless the Natchez who had taken his first scalp abstained from eating flesh and from sleeping with his wife for six months, the soul of the

[8] The italics are mine.

man he had killed would work his death by magic. For three nights after he had clubbed a human being to death the Fijian warrior had to sleep sitting up. In Central Australia the rest of a successful Arunta warrior is very broken. For nights he must lie awake listening to the cry of the little bird his fallen foe incarnates. Any failure to hear the cry would result in paralysis of right arm and shoulder. For a long time after his kill, a Monumbo warrior of New Guinea may touch no one. Were he to touch his wife or children, they would break out with sores. Among the Koita the homicide himself is endangered. He is supposed to grow thin and emaciated. Having been splashed with the blood of his victim, as the corpse rots, the slayer, they believe, wastes away.

The taboos growing out of this New Guinea belief as well as the other taboos on the victorious have been explained by the ethnologist as due to ghost fear. The homicide is subject to haunting by his victim, the simple-minded hold, and so the homicide must be exorcised or purified. However this may be, whatever reasons early man may have given himself, the beliefs and practises I have cited and many others analogous indicate, it seems to me, that very early man *felt* that the killing of other human beings was excessively repugnant;[4] with death in any form he was reluctant to be implicated. Very likely the upset the implication through killing caused him induced in him a special kind of ghost fear. Among the primitive, fear of ghosts or of evil spirits generally accompanies emotional disturbance.

That the killing itself had to be provoked by fear, by great fear, also seems probable, and that aversion to it had to be overcome by coöperation, by the courage inspired by numbers, by gregarious assurances, by social mysticism.[5] Holding then that "human nature" is not murderous, *i. e.*, men do not kill for the fun of killing, I suggest that war has been possible not because, according to the common view, men are naturally warlike, individually bellicose, but because they are naturally fearful and, above all, in their gregariousness highly mystical. Collective fears and uncritical gregarious impulses are thus the data the pacifist propagandist must consider. Expressions of combativeness or aggressiveness are not so much his concern[6] as are expressions of cowardice and of mysticism.

[4] Just as to-day feels the more conservative of the two sexes, and the sex more addicted to death taboos, *i. e.*, to mourning.

[5] Sometimes by specific acts of magic. "When old enough to join the fighting men the Zulu lads were beaten with the leaves of the cocoa-nut palm during a dance and 'medicine' was given to cause them not to care for or have pity upon any one." (*Reports Cambridge Anthropological Expedition to the Islands of Torres Straits*, V., 299. Cambridge, 1904.)

[6] At a recent meeting to organize a "League to Enforce Peace" ex-President Taft said: "So long as nations partake of the frailties of men who compose them, war is a possibility. . . ." And the speaker had here in mind, not individual fearfulness, I think, but individual bellicosity.

THE ORIGIN AND EVOLUTION OF LIFE UPON THE EARTH[1]

By HENRY FAIRFIELD OSBORN

COLUMBIA UNIVERSITY, AMERICAN MUSEUM OF NATURAL HISTORY

Lecture I. Part III

Biochemical Evolution of Bacteria—Evolution of Protoplasm and of Chromatin—The Fundamental Biologic Law—Chlorophyll and the Energy of Sunlight —Algæ.

Primary Stages of Biochemical Evolution in Bacteria

A BACTERIA-LESS earth and a bacteria-less ocean would soon be uninhabitable either for plants or animals; conversely, it is probable that bacteria-like organisms prepared both the earth and the ocean for the further evolution of plants and animals, and that life passed through a very long bacterial stage.

Owing to their minute size or actual invisibility bacteria are classified less by their shape than by their chemical actions, reactions, and interactions, the analysis of which is one of the triumphs of modern research. In the origin of life they lie half way between the hypothetical chemical pre-cellular stages (pp. 179–189) and the chemistry and definite cell structure of the lowliest plants or algae. The size of bacteria is in inverse ratio to their importance in the primordial and present history of the earth. The largest known are slightly above 1/20 of a millimeter in length and 1/200 of a millimeter in width.[2] The smaller forms range from 1/2000 of a millimeter to organisms on the very limit of microscopic vision, 1/5000 of a millimeter in size, and to the bacteria beyond the limits of microscopic vision, the existence of which is in-

[1] Fourth course of lectures on the William Ellery Hale Foundation, National Academy of Sciences, delivered at the meeting of the academy at Washington, on April 17 and 19, 1916. The author desires to express his special acknowledgments to Professor E. B. Wilson, of Columbia University, Dr. I. J. Kligler, of the American Museum of Natural History, Professor T. H. Goodspeed, of the University of California, and Dr. M. A. Howe, of the New York Botanical Garden, for notes and suggestions used in the preparation of this section.

[2] The influenza bacillus, $5/10 \times 2/10$ of a micron (1/1000 mm.) in size, and the germ of infantile paralysis, measuring 2/10 of a micron, are on the limit of microscopic vision. Beyond these are the ultra-microscopic bacteria, some of which can pass through a porcelain filter. See Jordan, Edwin O., 1908, pp. 52, 53.

ferred in certain diseases. The chemical constitution of these microscopic and ultra-microscopic forms is doubtless highly complex.

In their power of finding energy or food in a lifeless world the bacteria known as *prototrophic* or "primitive feeders" are not only the simplest known organisms, but it is probable that they represent the survival of a primordial stage of life chemistry. These bacteria derive both their energy and their nutrition directly from inorganic chemical compounds: such types were thus capable of living and flourishing on the lifeless earth even before the advent of continuous sunshine and long before the first chlorophyllic stage (Algæ) of the evolution of plant life. Among such bacteria possibly surviving from Archeozoic time is one of these "primitive feeders," namely, the *Nitroso monas* of Europe.[3] For combustion it takes in oxygen directly through the intermediate action of iron, phosphorus, or manganese, each of the single cells being a powerful little chemical laboratory which contains oxidizing catalyzers, the activity of which is accelerated by the presence of iron and of manganese. Still in the primordial stage *Nitroso monas* lives on ammonium sulphate, taking its energy (food) from the nitrogen of ammonium and forming nitrites. Living with it is the symbiotic bacterium *Nitrobacter,* which takes its energy (food) from the nitrites formed by *Nitroso monas,* oxidizing them into nitrates. Thus these two species illustrate in its simplest form our law of the *interaction of an organism* (*Nitrobacter*) *with its life environment* (*Nitroso monas*).[4]

The discovery of the chemical life of these bacteria marks an advance toward the solution of the problem of the origin of life as important as that attending the long prior discovery of chlorophyll. The prototrophic forms above noted are classed among the *nitrifying bacteria:* they take up the nitrogen of ammonia compounds and oxidize them first into nitrites and then into nitrates. Heraeus and Hüppe (1887) were the first to observe these forms in action in the soils and to prove that pre-chlorophyllic organisms were capable of development, with ammonium and carbon dioxide as their only sources of energy. Eight chemical "life elements" are involved in this process, namely, potassium, phosphorus, magnesium, sulphur, calcium, chlorine, nitrogen, and carbon. This discovery was confirmed by Winogradsky (1890, 1895), who showed that two symbiotic groups existed; one the *nitrite* formers, *Nitroso monas,* and the other the *nitrate* formers, *Nitrobacter.* These bacteria are not only independent of life compounds, but even small traces of organic carbon and nitrogen compounds are injurious to them. Later Nathanson (1902) and Beyjerinck (1904) showed that certain sulphur bacteria possess similar powers of converting ferrous to ferric oxide, and H_2S to SO_2. These organisms are widespread:

[3] Fischer, Alfred, 1900, pp. 51, 104.

[4] Jordan, Edwin O., 1908, pp. 492–497.

Nitroso monas is found in Europe, Asia, and Africa, while *Nitrobacter* appears to be almost universally distributed.

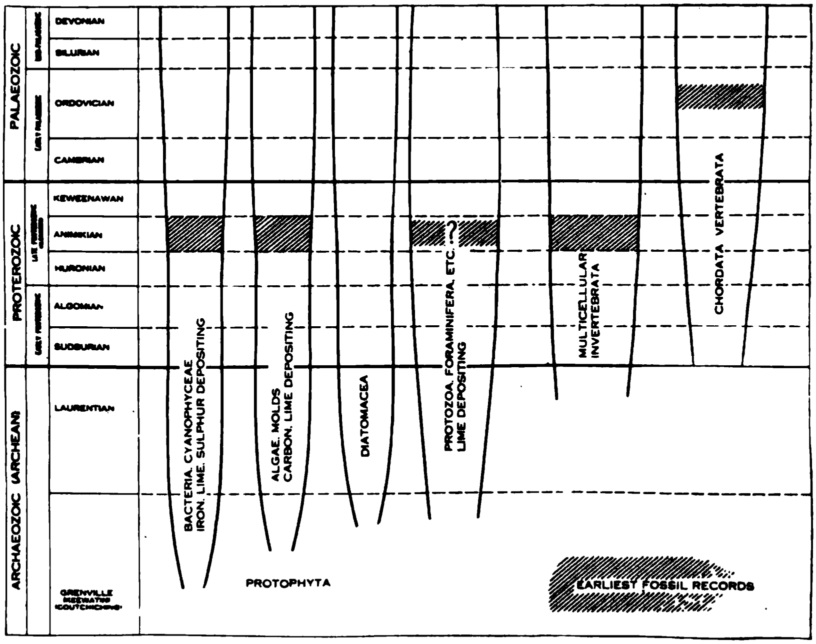

FIG. 1. PRE-CAMBRIAN PHYLÆ OF PLANT AND ANIMAL LIFE.

Such bacterial organisms may have flourished on the lifeless earth and prepared both the earth and the waters for the higher forms of plant life. The relation of the *nitrifying bacteria* to the decomposition of rocks is well summarized by Clarke in the following passage:[5]

> Even forms of life so low as the bacteria seem to exert a definite influence in the decomposition of rocks. A. Müntz has found the decayed rocks of Alpine summits, where no other life exists, swarming with the nitrifying ferment. The limestones and micaceous schists of the Pic du Midi, in the Pyrenees, and the decayed calcareous schists of the Faulhorn, in the Bernese Oberland, offer good examples of this kind. The organisms draw their nourishment from the nitrogen compounds brought down in snow and rain; they convert the ammonia into nitric acid, and that, in turn, corrodes the calcareous portions of the rocks. A. Stützer and R. Hartleb have observed a similar decomposition of cement by nitrifying bacteria. The effects thus produced at any one point may be small, but in the aggregate they may become appreciable. J. C. Branner, however, has cast doubts upon the validity of Müntz's argument, and further investigation of the subject seems to be necessary.

It is noteworthy that it is the *nitrogen derived from waters and soils,* rather than from the atmosphere, which plays the chief part in the life of these organisms; in a sense they represent a pre-carbon stage

[5] Clarke, F. W., 1916, p. 485.

of chemical evolution, also adaptation to an earth and water environment rather than to an atmospheric one.

In our study of the chemistry of the lifeless earth it has been shown how the life elements essential for the energy and nutrition of the nitrifying bacteria, namely, sodium, potassium, calcium and magnesium, with potassium nitrite and ammonium salts as a source of nitrogen, were probably accumulated in the waters, pools and soils. These bacteria were at once the soil-forming and the soil-nourishing agents of the primal earth; they throve in the presence of energy-liberating compounds of extremely primitive character. It is important to note that water and air are essential to vigorous ammonium reactions, whether at or near the surface. In arid regions at the present time the ammonifying bacteria do not exist on the dry surface rocks but act vigorously in the soils, not only at the surface, but also in the lower layers at depths of from six to ten feet where moisture is constant and the porous soil well aerated,[6] thus giving rise to a nitrogen-nourished substratum which explains the deep rooting of desert-dwelling plants.

A second point of great significance is that these nitrifying organisms are *heat-loving* and *light-avoiding;* they are dependent on the heat of the earth or of the sun, for, like all other bacteria, they carry on their activities best in the absence of sunshine, direct sunlight being generally fatal. The sterilizing effect of sunlight is due partly to the coagulation of the bacterial colloids by the rays of ultra-violet light. The sensitiveness of bacteria to sunlight cannot, however, be used as an argument against their geologic antiquity; on the contrary, their undifferentiated structure and their ability to live on inorganic foodstuffs *even without the aid of sunshine* seem to favor the idea that they represent a very primitive form of life.[7]

The great antiquity even of higher forms of bacteria feeding on atmospheric nitrogen is proved by the discovery, announced by Walcott[8] in 1915, of a species of pre-Paleozoic fossil bacteria attributed to "*Micrococcus*" but probably related rather to the existing *Nitroso coccus* which derives its nitrogen from ammonium salts. The *Nitroso coccus* is the form found in this country corresponding to the *Nitroso monas* of Europe. Its mode of life is identical with that of the *Nitroso monas.* These fossil bacteria were found in a section of a chlorophyll-bearing algal plant from the Newland limestone of the Algonkian of Montana, the age of which is estimated to be about thirty-three million years. They point to a very long antecedent stage of bacterial evolution.

6 Lipman, Charles B., 1912, pp. 7, 8, 16, 17, 20.

7 I. J. Kligler.

8 Walcott, Charles D., 1915, p. 256.

In the section (Fig. 2, *A*) shown by the arrow, there is a little chain of cells closely similar to those in the existing species of *Azotobacter,* an organism that fixes atmospheric nitrogen and converts it into a form utilizable by the plant. It is related to the *Nitroso coccus, Nitroso monas* and *Nitrobacter,* and lives on simple salts with mannite ($C_6H_{14}O_6$)[9] as a source of carbon.

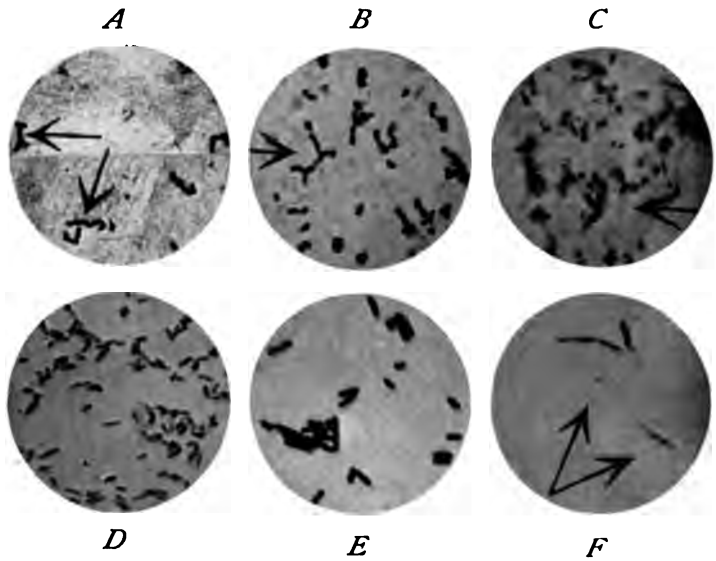

FIG. 2. *A.* Fossil bacteria from the Newland limestone (Algonkian) (after Walcott). *B.* Nitrifying bacteria found in soil. The arrow indicates a chain structure similar to that of Walcott's fossil bacteria. *C.* Nitrifying bacteria found in soils—a more complex type than the above. *D.* Nitrogen-fixing bacteria from the root nodules of legumes. Note the granular structure. *E.* Denitrifying bacteria found in soil and water. *F.* Bacteria stained to bring out the chromatin granules.

It was only after the chlorophyllic carbon-storing true plants had evolved that the second great group of nitrifying bacteria arose to develop the power of storing the *nitrogen of the atmosphere* through life association or symbiosis with plants, and of deriving their carbon, not from inorganic compounds, but from the carbohydrates of plants. Such users of atmospheric nitrogen and plant carbon include three general types: *B. radicicola,* associated with the root formation of legumes, *Clostridium* (anaerobic), and *Azotobacter* (aerobic).[10]

The gradual evolution of cell structure in these organisms can be partly traced despite their excessively minute size. The cell structure of the Algonkian and of the recent *Nitroso coccus* bacteria (Fig. 2, *A, B*) is very primitive and uniform in appearance, the protoplasm

[9] Mannite is needed by the higher forms of nitrifiers (*Azotobacter*), but not by the primitive types, and was probably not found until plant life flourished.

[10] Jordan, Edwin O., 1908, pp. 484–491.

being naked or unprotected: this primitive structure is also seen in *C*, another type of nitrogen fixer of the soil, which is chemically more complex because it can obtain its nitrogen either from the inorganic nitrogen compounds or from the organic nitrogen compounds (amino acids, proteins) which are fatal to the *Nitroso monas* and the *Nitrobacter* forms. The arrow points to a group of rods similar in appearance to those in *B*. A higher stage of granular structure appears in *D*, a nitrogen-fixer from the root nodules of legumes, which like *B* and *C* lives on inorganic chemical compounds but draws upon the atmosphere for nitrogen and upon sugar for its carbon: we observe an uneven granular structure in this cell. This may be an illustration of an early type of parasitic adaptation. The next type of bacterium (*E*) is a *denitrifier,* which derives its oxygen from the nitrates, reducing them to nitrites and free nitrogen and ammonia. A further stage of structural and chemical evolution is seen (*F*) in four elongated bacteria, each showing a rod-like but cellular form with a deeply staining chromatin or nuclear mass: the arrows point to cells showing these chromatin granules. This organism is chemically more complex in that it can secrete a powerful tryptic-like enzyme which enables it to utilize complex polypeptids and proteins (casein). Also it is an obligatory aerobic type, being unable to function in the absence of free oxygen.

It seems that the early course of evolution was in the line of developing a variety of complex molecules for performing a number of metabolic functions, and that the visible cell differentiation came later.[11] Step by step the chemical evolution and addition of increasingly complex actions, reactions, and interactions appears to correspond broadly with the structural evolution of the bacterial organism in its approach to the condition of a typical cell with its cell wall, protoplasm and chromatin nucleus. To sum up, the existing bacteria exhibit a series of primordial phases in the capture, storage and utilization of energy, and in the development of products useful to themselves and to other organisms and of by-products which cause interactions in other organisms. With the simplest bacteria which live directly on the lifeless world we find that most of the fundamental chemical energies of the living world are already established, namely,

(*a*) the protein and carbon storage, the primary food supply of the living world;

(*b*) the colloidal cell interior, with all the adaptations of colloidal suspensions, including

(*c*) the stimulating electric action and reaction of the metallic on the non-metallic elements; for example, the accelerations by iron, manganese, and other metals. Some bacteria carry positive, others negative ion charges;

[11] I. J. Kligler.

(*d*) the catalytic or enzyme action, both within and without the organism.

Thus the chemical composition of bacteria is analogous to that of the higher plant and animal cells, but no chlorophyll and no cellulose is found.

Bacterial suspensions manifest the characteristics of colloidal suspensions, namely, of fluids containing minute gelatinous particles which are kept in motion by molecular movement: these colloidal substances have the food value of protein and form the primary food supply of many Protozoa, the most elementary forms of animal life. Enzymes of three kinds exist, proteolytic, oxidizing and synthetic.[12] The proteolytic enzymes are similar to the tryptic enzymes of animals, being able to digest only the proteoses and amino acids but not the complex proteins. Powerful oxidizing enzymes are present but their character is not known. Synthetic enzymes must also exist though as yet there is no positive information concerning them. Like other forms of life, bacteria need oxygen for combustion in their intracellular actions and reactions; but free oxygen is not only unnecessary but actually toxic to the anaerobic bacteria, discovered by Pasteur in 1861, which derive their oxygen from inorganic and organic compounds. There is, however, a transitional group of bacteria, known as the *facultative anaerobes,* which can use either free, or combined oxygen, thus forming a link to all the higher forms of life in which free oxygen is an absolute essential. There is a group of the higher spore-forming bacteria which must have free oxygen. These constitute probably the last stage in bacterial evolution and form the link to the higher forms.

Armed with these physico-chemical powers, which may have been acquired one by one, the primordial bacteria mimic the evolution of the higher plant and animal world by an adaptive radiation into groups which respectively seek new sources of energy either directly from the inorganic world, or parasitically from the developing organic bacterial and plant foods in protein and carbohydrate form, the different groups living together in large communities and interacting chemically upon one another by the changes produced in the environment. For example, the iron bacteria discovered by Ehrenberg in 1838 obtain their energy from the oxidation of iron compounds, the insoluble oxide remaining stored in the cell and accumulating into iron as the bacteria die.[13] In general the beds of iron ore found in the pre-Cambrian strati-

[12] I. J. Kligler.

[13] It is claimed that iron bacteria play an important part in the formation of numerous small deposits of bog-iron ore and it seems possible that their activities may be responsible for extensive sedimentary deposits as well. Further, the fact of finding iron bacteria in underground mines opens the possibility that certain underground deposits of iron ore may have been formed by them. Harder, E. C., 1915, p. 311.

fied rocks, which have an estimated age of sixty million years, are believed to be of bacterial origin. Sulphur bacteria similarly obtain their energy from the oxidation of hydrogen sulphide.

Bacteria thus anticipate the plant world of algæ, diatoms and carbon-formers, as well as the animal world of protozoa and mollusca, by playing an important rôle in the formation of the new crust of the earth. This is observed in the primordial limestone depositions composed of calcium carbonate formed by bacterial action on the various soluble salts of calcium present in solution in sea-water, a process exemplified to-day[14] in the Great Bahama Banks where chalk mud is now precipitated through accumulation by *B. calcis*. Doubtless in the shallow continental seas of the primal earth such bacteria swarmed, as in the shallow coastal seas of to-day, having both the power of secreting and precipitating lime and, at the same time, of converting nitrogen combinations. In the warm oceanic waters the amount of lime deposited is larger and the *variety* of living forms is greater; but the *number* of living forms which depend for food on the algæ is less because the denitrifying bacteria which flourish in warm tropical waters deprive the algæ of the nitrates so necessary for their development. Again, where algal growth is scarce, the protozoic unicellular and multicellular life (plankton) of the sea, which lives upon the algæ, is also less abundant. This affords an excellent illustration of the great law of *the balance of the life environment through the equilibrium of supply of energy,* one aspect of the interaction of organisms with their life-environment. The denitrifying bacteria rob the waters of the energy needed for the lowest forms of plants, and these in turn are not available for the lowest forms of animal life. Thus in the colder waters of the oceans, where the denitrifying bacteria do not exist, the number of living forms is far greater, although their variety is far less.[15]

The so-called luminous bacteria also anticipate the plants and animals in light production,[16] which is believed to be connected with the oxidation of a phosphorescing substance in the presence of water and of free oxygen.

The parasitic life of bacteria began with their symbiotic relations with other bacteria, and was extended into intimate relations with the entire living world. The number of these organisms is inconceivable. In the daily excretion of a normal adult human being it is estimated that there are from 128 billion to 33 trillion bacteria, which would weigh approximately 5 5/10 grams when dried, and that the nitrogen in this dried mass would be about 0.6 gram, constituting nearly one half the total intestinal nitrogen.[17]

[14] Drew, George H., 1914, p. 44.

[15] Pirsson, Louis V., and Schuchert, Charles, 1915, p. 104.

[16] Harvey, E. Newton, 1915, pp. 230, 238.

[17] Kendall, A. I., 1915, p. 209.

EVOLUTION OF PROTOPLASM AND CHROMATIN, THE TWO STRUCTURAL COMPONENTS OF THE LIVING WORLD

It is still a matter of controversy[18] whether any bacteria, even at the present time, have reached the evolutionary stage of the typical cell with its cell wall, its contained protoplasm and its distinct nuclear form and inner substance known as chromatin. Some bacteriologists (Fischer) maintain that bacteria have neither nucleus nor chromatin; others admit the presence of chromatin but deny the existence of a formal nucleus; others contend that the entire bacterial cell has a chromatin content; while still others claim the presence of a distinctly differentiated nucleus containing chromatin. Most of them, however, are agreed as to the presence in bacteria of granules of a chromatin nature, while they leave as an open question the presence or absence of a structurally distinct nucleus. This conservative point of view is borne out by the fact that all the common bacteria have been found to contain *nuclein,* the specific nuclear protein complex; and is also sustained by the fact that the lowliest plants, the blue-green algæ (Cyanophyceæ), contain neither definitely formed nuclei nor chromatin bodies,[19] and are thus regarded as intermediate between bacteria and the higher green algæ (Chlorophyceæ).

It is also a matter of controversy among bacteriologists as to the very important question whether protoplasm or chromatin is the more ancient. Cell observers (Boveri, Wilson, Minchin), however, are thoroughly agreed on this point. Thus Minchin is unable to accept any theory of the evolution of the earliest forms of living beings which assumes the existence of forms of life composed entirely of protoplasm without chromatin.[20] All the results of modern investigations—the combined results, that is to say, of cytology and protistology—appear to him to indicate that the chromatin-elements represent the primary and original living units or individuals, and that the protoplasm represents a secondary product. As to whether chromatin or protoplasm is the more ancient, Boveri suggests that true cells arose through symbiosis between protoplasm and chromatin, and that the chromatin elements were primitively independent, living symbiotically with protoplasm. The more probable view is that of Wilson, that chromatin and protoplasm are coexistent in cells from the earliest known stages, in the bacteria and even probably in the ultra-microscopic forms.

The development of the cell theory after its enunciation in 1838 by Schleiden and Schwann followed first the differentiation of protoplasmic structure in the cellular tissues (histology). Since 1880 it has taken a new direction in investigating the *chemical and functional*

18 I. J. Kligler.

19 Loeb, Jacques, 1906, p. 106.

20 Minchin, E. A., 1916, p. 32.

separation of the chromatin. As protoplasm is now known to be the *expression,* so chromatin is now known to be the *seat* of heredity which Nägeli (1884) was the first to discuss as having a physico-chemical basis; the "idioplasm" postulated in his theory being realized in the actual structure of the chromatin as developed in the researches of Hertwig, Strasburger, Kölliker, and Weismann, who independently and almost simultaneously (1884, 1885) were led to the conclusion that the nucleus of the cell contains the physical basis of inheritance and that the chromatin is its essential constituent.[21] In the development from unicellular (Protozoa) into multicellular (Metazoa) organisms the chromatin is distributed through the nuclei to all the cells of the body, but Boveri has demonstrated that all the body cells lose a portion of their chromatin and only the germ cells retain the entire ancestral heritage.

Chemically, the most characteristic peculiarity of chromatin, as contrasted with protoplasm, is its phosphorus content.[22] It is also distinguished by a strong affinity for certain stains which cause its scattered or collected particles to appear intensely dark. Nuclein, which is probably identical with chromatin, is a complex albuminoid substance rich in phosphorus. The chemical, or molecular and atomic, constitution of chromatin infinitely exceeds in complexity that of any other form of matter or energy known. As intimated above (pp. 7, 8) it not improbably contains undetected chemical elements. Experiments made by Oskar, Gunther, and Paula Hertwig (1911–1914) resulted in the conclusion that in cells exposed to radium rays the seat of injury is chiefly, if not exclusively, in the chromatin:[23] these experi-

A

B

C

D

E

FIG. 3. CELL FORMS. *A. Achromatium,* a bacteria-like organism with diffused nucleus. *B.* Young ovarian egg of a sea-urchin. *C.* Ovarian egg of a sea-urchin. *D.* Root-tip of an onion. *E.* Embryo of *Sequoia sempervirens.* The mother-cells undergoing division. Two spindles of the reduction-division are shown.

21 Wilson, E. B., 1906, p. 403.

22 Minchin, E. A., 1916, pp. 18, 19.

23 Richards, A., 1915, p. 291.

ments point also to the separate and distinct chemical constitution of the chromatin.

The principle formulated by Cuvier, that the distinctive property of life is the maintenance of the individual specific form throughout

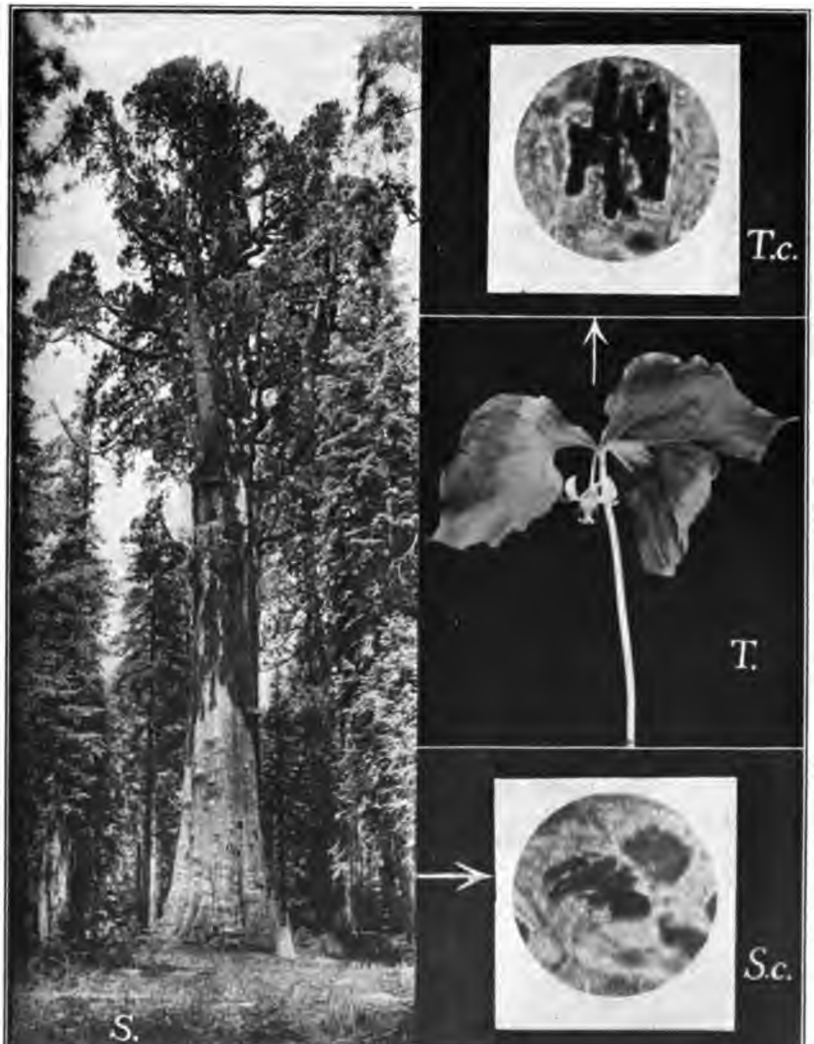

FIG. 4. *S. Sequoia Washingtonia* or *gigantea*. *Sc.* Cell of *Sequoia sempervirens*, showing the chromosomes (chromatin bodies). *T. Trillium*. *Tc.* Cell of *Trillium sessile*, var. *giganteum*, showing the chromosomes in the same phase and with the same magnification as in the cell of Sequoia (*Sc.*).

the incessant changes of matter which occur in the inflow and outflow of energy, acquires wider scope in the law of the continuity of the germ plasm (*i. e.*, chromatin), announced by Weismann in 1883, for it is in

the chromatin that the ideal form is not only preserved, but through subdivision carried into the germ cells of all the present and succeeding generations. The continuity of life since it first appeared in Archeozoic time is the continuity of the physico-chemical energies of the chromatin; the development of the individual life is an unfolding of the energies taken within the body under the directing agency of the chromatin; and the evolution of life is essentially the evolution of the chromatin energies. It is in the inconceivable physico-chemical complexity of the chromatin that life presents its most violent contrast to any of the phenomena observed within the lifeless world.

Although each organism has its specific constant in the cubic content of its chromatin, the bulk of this content bears little relation to the size of the individual. This is illustrated by a comparison of the chromatin content of the cell nucleus of *Trillium*, a plant about sixteen inches high, with that of *Sequoia sempervirens*, the giant redwood tree of California, which reaches a height of from 200 to 300 feet and attains an age of several thousand years (Fig. 5). The chromatin content of such a nucleus is measured by the bulk of the chromosome rods of which it is composed. In the sea-urchin the size of the sperm nucleus, the most compact type of chromatin, has been estimated as about 1/100,000,000 of a cubic millimeter or 10 cubic microns in bulk.[24]

Within such a chromatin bulk there is yet ample space for an incalculable number of minute particles of matter. According to the figures given by Rutherford[25] in the first Hale Lecture the diameter of the sphere of action of an atom is about 1/100,000,000 of a centimeter, or 1/10,000,000 of a millimeter, or 1/10,000 of a micron—the unit of microscopic measurement. The electrons released from atoms of matter are only 1/1800 of the mass of the hydrogen atom, the lightest known to science, and thus the mass of an electron would be only 1/18,000,000 of a micron. These figures help us in some measure to conceive of the chromatin as a microcosm made up of an almost unlimited number of mutually acting, reacting and interacting particles; but

[24] E. B. Wilson, letter of June 28, 1916.

[25] It is necessary, observes Rutherford, to be cautious in speaking of the diameter of an atom, for it is not at all certain that the actual atomic structure is nearly so extensive as the region through which the atomic forces are appreciable. The hydrogen atom is the lightest known to science, and the average diameter of an atom is about 1/100,000,000 of a centimeter; but the negatively charged particles known as electrons are about 1/1800 of the mass of the hydrogen atom. . . . These particles travel with enormous velocities of from 10,000 to 100,000 miles a second. . . . The alpha particles produce from the neutral molecules a large number of negatively charged particles called ions. The ionization due to these alpha particles is measurable. . . . In the phosphorescence of an emanation of pure radium the atoms throw off the alpha particles with velocities of 10,000 miles a second, and each second five billion alpha particles are projected. Rutherford, Sir Ernest, 1915, pp. 113, 128.

while we know it to be the physical basis of inheritance and the presiding genius of all phases of development, we can not form the slightest conception of the mode in which the chromatin speck controls the destinies of *Sequoia gigantea* and lays down all the laws of its being for a period of five thousand years.

We are equally ignorant as to how the chromatin responds to the actions, reactions and interactions of the body cells, of the life environment, and of the physical environment, so as to call forth a new adaptive character,[26] unless it be through some catalytic agencies (p. 8). Yet in pursuing the history of the evolution of life upon the earth we may constantly keep before us our fundamental biologic law[27] that evolution lies within four complexes of energies, which are partly visible and partly invisible, namely:

1. The evolution of the physical environment;
2. The individual development of the organism, namely, of its protoplasm controlled and directed by its chromatin;
3. The heredity evolution of the chromatin with its constant addition of new powers and energies;
4. The evolution of the life environment, beginning with the protocellular chemical organisms and such intermediate organisms as bacteria, and followed by such cellular and multicellular organisms as the higher plants and animals.

Incessant competition, selection, intraselection (Roux), and elimination between all parts of organisms in their chromatin energies, in their protoplasmic energies, and in their actions, reactions and interactions with the living environment and with the physical environment.

Chlorophyll and the Energy of Sunlight

As bacteria seek their energy in the geosphere and hydrosphere, chlorophyll is the agent which connects life with the atmosphere, collecting the carbon from its union with oxygen in carbon dioxide. The utilization of the energy of sunlight in the capture of carbon from the atmosphere through the agency of chlorophyll marked the second great phase in the evolution of life, following the first bacterial phase. The chief energy elements, nitrogen and (less frequently) carbon, were captured by bacteria through molecule-splitting in the presence of heat, but without the powerful aid of sunlight.

It is the fossilized tissue of plants which leads us to the conclusion that the agency of chlorophyll is also extremely ancient. Near the base of the Archean rocks[28] graphites are observed in the Grenville series

[26] Wilson, E. B., 1906, p. 434.
[27] Osborn, H. F., 1912.
[28] Pirsson, Louis V., and Schuchert, Charles, 1915, p. 545.

and in the Adirondacks. The very oldest metamorphosed sedimentaries are mainly composed of shales containing carbon.

Since the carbohydrates constitute the basal energy supply of the entire plant and animal world,[29] we may examine the process even more closely than we have done above (p. 172). As a reservoir of life energy which is liberated by oxidation, hydrogen exceeds any other element in the heat it yields, namely, 34.5 calories per gram, while carbon yields 8.1 calories per gram.[30] The results of the most recent researches are presented by Wager.[31]

> The plant organ responds to the directive influence of light by a curvature which places it either in a direct line with the rays of light as in grass seedlings, or at right angles to the light as in ordinary foliage leaves. . . . Of the light that falls upon a green leaf a part is reflected from its surface, a part is transmitted, and another part is absorbed. That which is reflected and transmitted gives to the leaf its green color; that which is absorbed, consisting of certain red, blue, and violet rays, is the source of the energy by means of which the leaf is enabled to carry on its work.
>
> The extraordinary molecular complexity of chlorophyll has recently been made clear to us by the researches of Willstätter and his pupils; Usher and Priestley and others have shown us something of what takes place in chlorophyll when light acts upon it; and we are now beginning to realize more fully what a very complex photo-sensitive system the chlorophyll must be, and how much has yet to be accomplished before we can picture to our minds with any degree of certainty the changes that take place when light is absorbed by it. But the evidence afforded by the action of light upon other organic compounds, especially those which, like chlorophyll, are fluorescent, and the conclusion according to modern physics teaching that we may regard it as practically certain that the first stage in any photo-chemical reaction consists in the separation, either partial or complete, of negative electrons under the influence of light, leads us to conjecture that, when absorbed by chlorophyll, the energy of the light-waves becomes transformed into the energy of electrified particles and, that this initiates a whole train of chemical reactions resulting in the building up of the complex organic molecules which are the ultimate products of the plant's activity.

Chlorophyll absorbs most vigorously the rays between B and C of the solar spectrum,[32] which are the most energizing; the effect of the rays between D and E is minimal; while the rays beyond F again become effective. As compared with the primitive bacteria in which nitrogen figures so largely, chlorophyllic plant tissues consist chiefly of carbon, hydrogen, and oxygen, the chief substance being cellulose ($C_6H_{10}O_5$),[33] while in some cases small amounts of nitrogen are found, and also mineral substances, potassium, magnesium, phosphorus, sulphur, and manganese. On the contrary, it is the invariable presence of nitrogen

[29] Moore, F. J., 1915, p. 213.

[30] Henderson, Lawrence J., 1913, p. 245.

[31] Wager, Harold, 1915, p. 468.

[32] Loeb, Jacques, 1906, p. 115.

[33] Pirsson, Louis V. and Schuchert, Charles, 1915, p. 164.

which distinguishes the proteins of the bacteria: nitrogen is also a large constituent of animal proteins.

PERCENTAGE OF ELEMENTS IN THE PROTEINS[34]

Carbon	50.0 – 55.0
Hydrogen	6.9 – 7.3
Oxygen	19.0 – 24.0
Nitrogen	18.0 – 19.0
Sulphur	0.3 – 2.4

Closest to the bacteria in structure are the so-called "blue-green algæ" or Cyanophyceæ, found everywhere in fresh and salt water and even in hot springs, as well as on damp soil, rocks, and bark. The characteristic color of the Red Sea is due to a free-floating form of these blue-green algæ which in this case are red. Unlike the true algæ the cell nucleus of the Cyanophyceæ ordinarily is not sharply limited by a membrane, and there is no evidence of distinct chlorophyll-bodies, although chlorophyll is present. Their only method of reproduction is that known as vegetative multiplication, in which an ordinary working cell (individual) divides to form two new individuals. The sinter deposits of hot springs and geysers in Yellowstone Park are attributed to the presence of Cyanophyceæ.[35]

With the appearance of the true algæ the earth-forming powers of life become still more manifest and few geologic discoveries of recent times are more important than those growing out of the recognition of algæ as earth-forming agents. As early as 1831 Lyell remarked their rock-forming powers. It is now known that among the various lower organisms concerned in earth-building, the algæ rank first, the foraminifera second, and the corals third. In a forthcoming work by F. W. Clarke and W. C. Wheeler they remark upon these earth-building activities as follows:

> The calcareous algæ are so important as reef builders, that, although they are not marine invertebrates in the ordinary acceptance of the term, it seemed eminently proper to include them in this investigation. In many cases they far outrank the corals in importance, and of late years much attention has been paid to them. On the atoll of Funafuti, for example, the algæ *Lithothamnium* and *Halimeda* rank first and second in importance, followed by the foraminifera, third, and the corals, fourth.

Algæ are probably responsible for the formation of the very ancient limestones; those of the Grenville series at the very base of the pre-Cambrian are believed to be over 60,000,000 years of age. The algal flora of the relatively recent Algonkian time,[36] together with calcareous

[34] Moore, F. J., 1915, p. 199. Nucleic proteins contain a notable amount of phosphorus as well.

[35] Coulter, John Merle, 1910, pp. 10–14.

[36] Walcott, Charles D., 1914.

bacteria, developed the massive limestones of the Tetons. Clarke observes:

We are now beginning to see where the magnesia of the limestones comes from and the algæ are probably the most important contributors of that constituent.

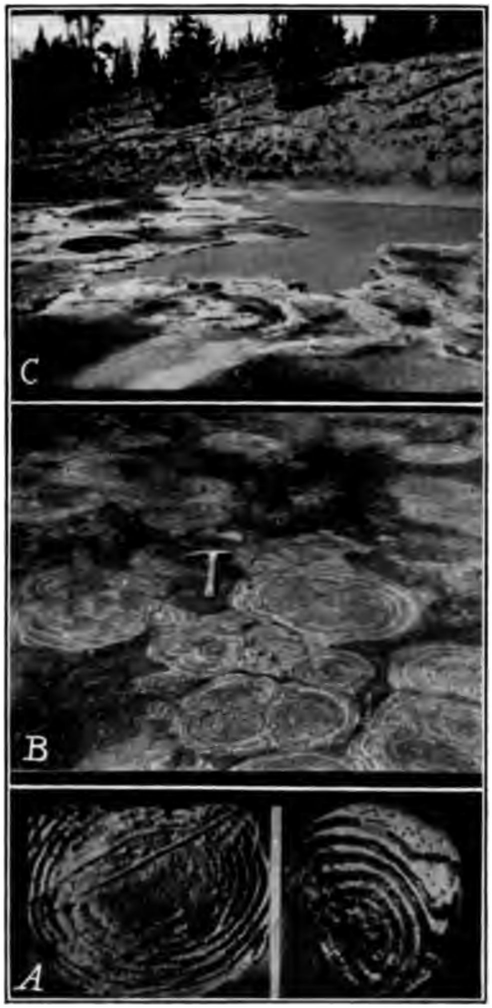

FIG. 5. *A*. Fossil algæ (*Newlandia concentrica, Newlandia frondosa*) from the Algonkian Belt Series of Montana. Walcott. *B*. Fossil calcareous algæ (*Cryptozoon proliferum*) from the Cambrian limestone of Lester Park near Saratoga Springs, New York. *C*. An algal pool near the Great Fountain Geyser, Yellowstone Park. Walcott. Photographed by H. P. Cushing.

Thus representatives of the Rhodophyceæ contribute as high as 87 per cent. of calcium carbonate and 25 per cent. of magnesium carbonate.

Species of *Halimeda,* however, calcified algæ belonging to the very different class Chlorophyceæ, are important agents in reef-building and land-forming, yet are almost non-magnesian.[37]

The Grenville series at the base of the Paleozoic is essentially calcareous, with a thickness of over 94,000 feet, nearly eighteen miles, more than half of which is calcareous.[38] Thus it appears probable that the surface of the primordial continental seas swarmed with these minute algæ, which served as the chief food magazine for the floating protozoa; but it is very important to note that their life is absolutely dependent

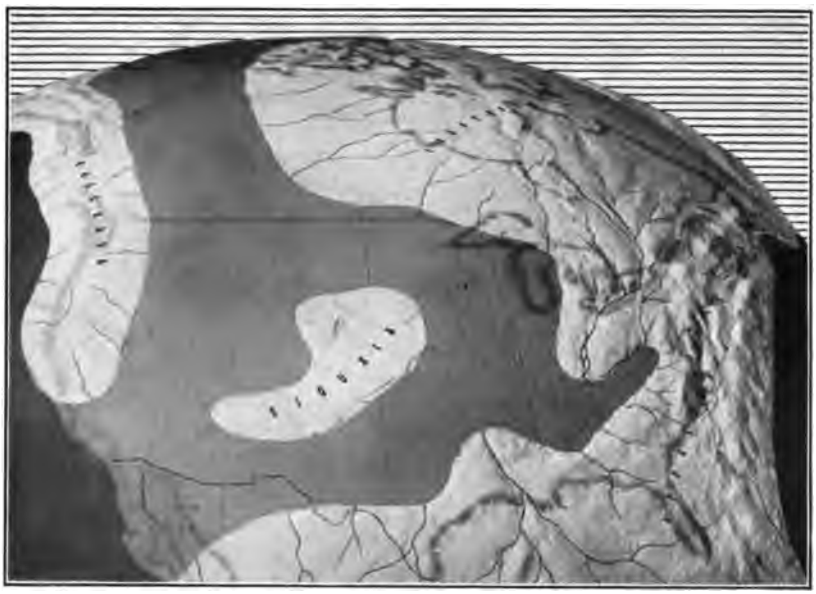

FIG. 6. NORTH AMERICA IN PRE-CAMBRIAN (CROIXIAN) TIME. Detail from globe model by Chester A. Reeds and George Robertson, after Schuchert.

upon phosphorus and other earth-borne constituents of sea-water, as well as upon nitrogen, also earth-borne, and due to bacterial action; for where the denitrifying bacteria rob the sea-water of its nitrogen content the algæ are much less numerous.[39] Silica is also an earth-borne, though mineral, constituent of sea-water which forms the principal skeletal constituent of the shells of diatoms, minute floating plants especially characteristic of the cooler seas which form the siliceous ooze of the sea-bottoms.

(*To be continued*)

[37] M. A. Howe, letter of February 24, 1916.

[38] Pirsson, Louis V., and Schuchert, Charles, 1915, pp. 545, 546.

[39] *Op. cit.*, p. 104.

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THE PROGRESS OF SCIENCE

SCIENTIFIC APPOINTEMNTS UNDER THE GOVERNMENT

A SCIENTIFIC journal must avoid the discussion of party politics, but it is legitimate to point out that the two leading parties have adopted platforms which, as far as their principles go, might almost be interchanged, and have nominated candidates who have much in common, both of them being lawyers, university professors and sons of clergymen. In view of these circumstances it is of interest to those concerned with science that Mr. Hughes in his first campaign speeches should select as one of his two leading issues the appointments by President Wilson to scientific offices under the government. This would not have been a vital political issue a few years ago, and it is certainly gratifying that it should now have become so, more especially as both parties and both candidates profess the same desirable principles and only dispute about the extent to which they have been maintained.

In opening his campaign at Detroit, Mr. Hughes charged the administration with having displaced the scientific heads of the census and of the coast and geodetic survey with men not having scientific qualifications. The word "displaced" is ambiguous and was perhaps intended to be so, and the reply of the secretary of commerce that both men had "voluntarily retired" is also, and it may be purposely, ambiguous. Men familiar with university affairs, like the two candidates for the presidency, know that professors sometimes have their resignations presented to them. It is allowable to say either that Dr. Wilson displaced Dr. Patten as president of Princeton University or that Dr. Patten resigned and was succeeded by Dr. Wilson. As a matter of fact, Dr. Durand's resignation as director of the census was forced, and Dr. Tittman, who was sixty-five years old and in indifferent health, resigned voluntarily from the Coast and Geodetic Survey.

The vulnerable point in the action of the administration is the appointment of their successors. Mr. William J. Harris, appointed director of the census, was chairman of the democratic state committee of Georgia and the appointment appears to have been for political reasons, as has unfortunately so often happened in the bureau of the census, where the extension of civil service rules has been least adequate. E. Lester Jones, when appointed superintendent of the coast and geodetic survey to succeed Dr. Tittman, was deputy commissioner of fisheries. His appointment to that office and his promotion to the head of the survey in the same department appear to have been personal rather than political. He has proved to be an efficient executive, but his appointment to both offices certainly violated the principle that these positions should be held by experts.

It can not, however, be denied that there are two sides to this question. Under modern conditions a distinguished man of science is likely to be a good executive, but the number of scientific men available for a position of this character is limited, and it is by no means certain that it is desirable to divert the skilled expert from his research work to an executive position. Another solution of the problem would be to make the heads of bureaus purely administrative officers, to be filled by men used to administrative work, but for the scientific policy of the bureau

to be decided by a committee of its scientific experts and for the more eminent of these to receive salaries not smaller than that of the executive head.

Mr. Hughes has not pointed out, as an impartial judge might have done, that the two scientific appointments mentioned are the only ones in which the president is open to criticism, or that he is the first president who has officially asked the advice of scientific men on such points. At the meeting of the council of the American Association for the Advancement of Science, held in Washington on April 22, 1913, shortly after President Wilson's installation, the following resolution, proposed by Mr. Cattell, was passed:

WHEREAS, It is eminently desirable that scientific men especially skilled in their departments be appointed as heads of the scientific bureaus of the government, therefore,

Resolved, That a committee of three be appointed to communicate to the President of the United States that it is the opinion of the council of the American Association for the Advancement of Science that a scientific man skilled in meteorology should be selected as the Chief of the Weather Bureau.

The committee waited on the president who requested the secretary of agriculture to consult with the committee of the association. The secretary of agriculture at that time stated that no appointment in the department of agriculture had been made or would be made for political reasons, or even be given to a man who sought the office. The committee of the American Association called the attention of the secretary to the fact that the National Academy of Sciences is by law the scientific adviser of the government, and the president, as far as we are aware for the first time since the law was enacted in 1863, asked the advice of the academy on an appointment. A committee of experts of the academy recommended three men skilled in meteorology and fitted for the office of chief of the weather bureau, and one of these was appointed by the president. In like manner the commissioner of fisheries was appointed from candidates proposed by the American Society of Naturalists and the American Zoological Society. In other cases President Wilson has asked and followed the advice of scientific bodies and scientific men, and his record in this respect is certainly better than that of any of his recent predecessors. We can only hope that he himself or Mr. Hughes, as the case may be, will still further improve this record in the course of the next four years.

A NATIONAL RESEARCH COUNCIL

THE National Academy of Sciences has appointed, at the request of the president of the United States, an organizing committee to make recommendations concerning a national research council of the United States. This committee, which consists of George E. Hale, director of the Mt. Wilson Solar Observatory, chairman, Edwin G. Conklin, professor of zoology at Princeton University, Simon Flexner, director of the laboratories of the Rockefeller Institute for Medical Research, Robert A. Millikan, professor of physics in the University of Chicago, and Arthur A. Noyes, professor of chemistry in the Massachusetts Institute of Technology, have prepared a preliminary statement concerning the plans of the council.

Its purpose is to bring into cooperation existing governmental, educational, industrial and other research organizations, with the object of encouraging the investigation of natural phenomena, the increased use of scientific research in the development of American industries, the employment of scientific methods in strengthening the national defence, and such other applications of science as will promote the national security and welfare.

The council will be composed of leading American investigators and engineers, representing the army, navy, Smithsonian Institution and various scientific bureaus of the government; educational institutions and research endowments; and the research divisions

of industrial and manufacturing establishments. Research committees of two classes will be appointed: central committees, representing various departments of science, comprised of leading authorities in each field, selected in consultation with the president of the corresponding national society; local committees in cooperating institutions engaged in research.

The following plan of procedure is proposed:

1. The preparation of a national inventory of equipment for research, of the men engaged in it, and of the lines of investigation pursued in cooperating government bureaus, educational institutions, research foundations and industrial research laboratories; this inventory to be prepared in harmony with any general plan adopted by the proposed government council of national defence.
2. The preparation of reports by special committees, suggesting important research problems and favorable opportunities for research in various departments of science.
3. The promotion of cooperation in research, with the object of securing increased efficiency; but with careful avoidance of any attempt at coercion or intereference with individual freedom and initiative.
4. Cooperation with educational institutions, by supporting their efforts to secure larger funds and more favorable conditions for the pursuit of research and the training of students in the methods and spirit of investigation.
5. Cooperation with research foundations and other agencies desiring to secure a more effective use of funds available for investigation.
6. The encouragement in cooperating laboratories of researches designed to strengthen the national defence and to render the United States independent of foreign sources of supply liable to be affected by war.

It is not clear why there should be a discrimination between educational institutions and research foundations, so that the former should be aided in securing larger funds and the latter in using their funds more effectively, and some scientific men may think it more desirable to cooperate with other nations in producing supplies where this can be done to the best advantage, rather than to prepare for war. The National Research Council should, however, be able to perform a useful service, more especially in directing public attention to the importance of scientific research for the welfare of the nation and of the world.

THE EPIDEMIC OF INFANTILE PARALYSIS

THERE have been in New York City up to August 20 about 7,000 cases of infantile paralysis and 1,600 deaths and the epidemic has spread to a serious extent in adjacent parts of the state and in New Jersey. The only alleviating circumstance in connection with this disease, which from its ill-understood origin and mode of transmission, produces in these days somewhat the same psychologic effects as smallpox and the plague in past days, is that thorough measures have been undertaken to check the disease and that these may be extended to other diseases which entail an even greater amount of suffering and death than poliomyelitis.

Efforts are also being made in many places to obtain scientific information concerning the disease. Thus at the suggestion of Dr. Haven Emerson, health commissioner of New York City, a conference took place at the College of Physicians and Surgeons, early in August, of which Dr. Simon Flexner was chosen as chairman. A committee was appointed to consider all the phases of laboratory investigation, to suggest subjects and in some instances lines of study in connection with the disease. This committee consists of Dr. Flexner, Professor Ludvig Hektoen, University of Chicago, Professor Hans Zinsser, College of Physicians and Surgeons, New York; Professor Richard M. Pearce, Jr., University of Pennsylvania; Professor James W. Jobling, Vanderbilt University; Surgeon George W. McCoy, director of the hygienic laboratory at Washington, and Dr. Theobald Smith, of the Rockefeller Institute. Another committee was appointed to consider practical measures

Sylvanus Phillips Thompson,
whose death deprives England of one of its most distinguished physicists.

that might apply in the suppression of the epidemic. This committee consists of Dr. Victor C. Vaughan, University of Michigan, chairman; Professor Milton J. Rosenau, Harvard; Dr. William H. Park, department of health, New York City; Dr. Francis W. Peabody, Boston; Dr. John Howland, Johns Hopkins; Dr. Augustus B. Wadsworth, director of the state laboratories, Albany, and Professor Charles C. Bass, Tulane University. The members of the conference were conducted through the infantile paralysis wards of the Willard Parker Hospital and were present at a clinic held there. The research workers will carry with them cultures of the disease and will work out various lines of investigation in their own laboratories. The report of the conference was presented to Dr. Haven Emerson on August 4 and lays stress on:

1. The early recognition and notification of the disease, and

2. The immediate isolation of patients and cases of suspicious illness. Furthermore, on account of incomplete knowledge concerning the disease, measures known to be effective in checking the spread of other infections should be applied and these are, particularly, personal hygiene, cleanliness of person and surroundings, and care of food, which should be thoroughly cooked.

The special problems suggested for study are the following:

1. Methods of culture of the virus of poliomyelitis, with especial reference to corroboration of previous work, to simplification of methods, and to the distribution of the virus in the body of patients.

2. The immunologic reactions of patients, supposed carriers of the virus, and others.

3. The virulence for animals, of the crude virus, in order to determine if possible whether there are any differences in the virus causing outbreaks in different parts of the country as well as to discover, perchance, more susceptible animals for experimental purposes than are now available.

4. The microscopic study of the secretions of the nose and throat and of the intestinal contents of patients suffering from poliomyelitis, persons who have come in close contact with such patients, and others.

5. The transmission of the disease by insects and domestic animals and other possible modes of transmission.

6. The study of practical methods of disinfection.

SCIENTIFIC ITEMS

We record with regret the death of John B. Murphy, the distinguished Chicago surgeon; of William Cole Esty, professor emeritus of mathematics, Amherst College; of William Simon, professor of chemistry at the College of Physicians and Surgeons, Baltimore; of Sir Victor Horsley, the distinguished English surgeon, and of Sir William Ramsay, the eminent British chemist.

The Royal Society of Edinburgh has elected as foreign honorary fellows, Professor D. H. Campbell, professor of botany, Leland Stanford University; General W. C. Gorgas, U. S. Army, and Professor E. C. Pickering, director of Harvard College Observatory.—The Hon. Bertrand Russell, F.R.S., one of the most distinguished English students of philosophy, was recently fined for issuing pamphlets to conscientious objectors to military service and deprived of his lectureship at Trinity College, Cambridge; now it is said he has been refused a passport to visit America to keep his engagement to lecture at Harvard University.

The vocational-educational bill, providing for federal cooperation with the states in promoting agricultural and industrial education, makes an annual appropriation beginning at $500,000 and increasing each year by $250,000 until $3,000,000 is reached, to be apportioned to the states in proportion to their rural population.—The jury in the Surrogates' Court of New York City has declared invalid the will of Amos F. Eno, according to which Columbia University was made the residuary legatee and would receive an amount estimated at over four million dollars. It is understood that Columbia University will seek to obtain a new trial.

Vol. 3, No. 4 OCTOBER, 1916

THE SCIENTIFIC MONTHLY

EDITED BY J. McKEEN CATTELL

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THE SCIENCE PRESS

LANCASTER, PA. GARRISON, N. Y.

NEW YORK: SUB-STATION 84

SINGLE NUMBER, 30 CENTS YEARLY SUBSCRIPTION, $3.00

THE SCIENTIFIC MONTHLY

OCTOBER, 1916

THE ORIGIN AND EVOLUTION OF LIFE UPON THE EARTH, III[1]

By HENRY FAIRFIELD OSBORN

COLUMBIA UNIVERSITY, AMERICAN MUSEUM OF NATURAL HISTORY

LECTURE I. PART IV

Contrasts between Plant and Animal Evolution—Mutation of de Vries in Plants—Resemblances between Plant and Animal Evolution—Origin of Animals —Life of Lower and Middle Cambrian Times—Adaptive Radiation of the Invertebrata—Mutation of Waagen in Molluscs.

Contrasts between Plant and Animal Evolution

In their evolution, while there is a continuous specialization and differentiation of the modes of obtaining energy, plants do not attain a higher chemical stage than that observed among the bacteria and algæ, except in the parasitic forms which feed both upon the plant and animal compounds. In the energy which they derive from the soil plants continue to be closely dependent upon bacteria, because they derive their nitrogen from nitrates generated by bacteria and absorbed along with water by the roots. In their relations to the atmosphere and to sunlight the chlorophyllic organs differentiate into the marvelous variety of leaf forms, and these in turn are separated upon stems and branches which finally lead into the creation of woody tissues and the clothing of the earth with forests. Through the specialization of leaves in connection with the germ cells flowers are developed, and plants establish a marvelous series of life environment interactions, first, with the developing insect life, and finally with the developing bird life.

The main lines of the ascent and classification of plants are traced by paleobotanists partly from their structural evolution, which is

[1] Fourth course of lectures on the William Ellery Hale Foundation, National Academy of Sciences, delivered at the meeting of the academy at Washington, on April 17 and 19, 1916. The author desires to express his special acknowledgments to Dr. M. A. Howe, of the New York Botanical Garden; Professor Charles Schuchert, of Yale University; Professor Gary N. Calkins, of Columbia University and Mr. Roy W. Miner, of the American Museum of Natural History, for notes and suggestions used in the preparation of this section.

almost invariably adapted to keep their chlorophyllic organs in the sunlight[2] in competition with other plants; and partly from the evolution of their reproductive organs, which pass through the primitive spore stage into various forms of sexuality, with, finally, the development of the seed-habit and the dominance of the sporophyte.[3] It is a striking peculiarity of plants that the locomotive powers evolve chiefly in connection with their reproductive activities, namely, with the movements of the germ cells: in this respect and in their fundamentally different sources of energy they represent the widest contrast to animal evolution. One of the most striking features of plant evolution is the development of a great variety of automatic migrating organs, especially in the seed and embryonic stages, by which they are mechanically propelled through the air or water. Plants are otherwise dependent on the motion of the atmosphere and of the water for the migration of their germs and embryos and of their adult forms into favorable conditions of environment.

In the absence of a nervous system the remarkable actions and reactions which plants exhibit to stimuli are purely of a physico-chemical nature. The interactions between different tissues of plants, which become extraordinarily complex in the higher and larger forms, are probably sustained through chemical catalysis and the circulation through the tissues of accelerating and retarding agents in the nature of enzymes or hormones. It is a very striking feature of plant development and evolution that, although entirely without the coordinating agency of a nervous system, all parts are kept in a condition of perfect correlation. This fact is consistent with the comparatively recent discovery that a large part of the coordination of animal organs and tissues which was formerly attributed to the nervous system is now known to be catalytic. Throughout the evolution of plants the fundamental distinctions between the chromatin and the protoplasm are sustained exactly as among animals.

It would appear from the researches of de Vries[4] and other botanists that the sudden alterations of structure and function which may be known as *mutations of de Vries*[5] are of far more general occurrence among plants than among animals. Such mutations are attributable to sudden alterations of molecular and atomic constitution. Sensitiveness to the biochemical reactions of the physical environment should theoretically be more evident in organisms like plants which derive their energy directly from inorganic compounds which are constantly changing their chemical formulæ with the conditions of moisture, of

[2] Wager, Harold, 1915, p. 468.

[3] M. A. Howe.

[4] de Vries, Hugo, 1901, 1903, 1905.

[5] As distinguished from the earlier defined *Mutations of Waagen*, 332.

aridity, of temperature, of chemical soil content; than in organisms like animals which secure their food compounds ready-made by the plants and possessing comparatively similar and stable chemical formulæ. Thus a plant transferred from one environment to another exhibits much more sudden and profound changes than an animal, for the reason that all the sources of plant energy are profoundly changed while the sources of animal energy are only slightly changed. The highly varied chemical sources of plant energy are, in other words, in striking contrast with the comparatively uniform sources of animal energy which are primarily the carbohydrates and the proteins formed by the plants.

In respect to *character-origin,* therefore, plants may in accordance with the de Vries mutation hypothesis exhibit discontinuity or sudden changes of form and function more frequently than animals. In respect to *character-coordination,* or the harmonious relations of all their parts, plants are inferior to animals only in their sole dependence on catalytic enzymes; while animal characters are coordinated both through catalytic enzymes and through the nervous system. In respect to *character-velocity,* or the relative rates of movement of different parts of plants both in individual development and in evolution, plants appear to compare very closely with animals.

This law of changes in character-velocity, both in individual development (ontogeny) and in racial development (phylogeny), is one of the most mysterious and difficult to understand in the whole order of biologic evolution, for it is distinctively a chromatin phenomenon, although visible in protoplasmic form. Among plants it is illustrated by the recent observations of Coulter on the relative time of appearance of the reproductive cell organs (archegonia) in the two great groups of gymnosperms, the Cycads and the Conifers, as follows: in the Cycads, which are confined to warmer climates, the belated appearance of the archegonium persists; in the Conifers, in adaptation to colder climates and the shortened reproductive season, the appearance of the archegonium is thrust forward into the early embryonic stages. Finally, in the flowering plants (Angiosperms) the backward movement of this character continues until the third cellular stage of the embryo is reached. This is but one illustration among hundreds which might be chosen to show how character-velocity in plants follows exactly the same laws as in animals, namely, characters are accelerated or retarded in race evolution and in individual development in adaptation to the environmental and individual needs of the organism. We shall see this mysterious law beautifully illustrated among the vertebrates, where of two characters, lying side by side, one exhibits inertia, the other momentum.

THE ORIGIN OF ANIMAL LIFE

A prime biochemical characteristic in the origin of animal life is the derivation of energy neither directly from the water, from the earth, nor from the earth's or sun's heat, as in the most primitive bacterial stages; nor from sunshine, as in the chlorophyllic stage of plant life; but from its stored form in the bacterial and plant world.

We have no idea when the first unicellular animals known as protozoa appeared. Since the protozoa feed freely upon bacteria it is possible they may have evolved during the bacterial epoch; it is known that protozoa are at present one of the limiting factors of bacterial activity in the soil and it is even claimed[6] that they have a material effect on the fertility of the soil through the consumption of nitrifying bacteria.

On the other hand, it may be that the protozoa appeared during the algal epoch or subsequent to the chlorophyllic plant organisms which now form the primary food supply of the freely floating and swimming protozoan types. A great number of primitive flagellates are saprophytic, using only dissolved proteids as food.[7]

Apart from the parasitic mode of deriving their energy, even the lowest forms of animal life are distinguished both in the embryonic and adult stages by their locomotive powers. Heliotropic or sun reactions, or movements towards sunlight, are manifested at an early stage of animal evolution. In this function there appear to be no boundaries between animals and the embryos of plants.[8] As cited by Loeb and Wasteneys, Paul Bert in 1869 discovered that *Daphnia* swims towards the light in all parts of the visible spectrum, but most rapidly in the yellow or in the green. More definitely, Loeb observes that there are two particular regions of the spectrum, the rays of which are especially effective in causing organisms to turn, or to congregate, towards them: these regions lie (1) in the blue, in the neighborhood of a wave-length of 477 $\mu\mu$, and (2) in the yellowish-green, in the region of $\lambda = 534\,\mu\mu$; and these two wave-lengths affect different organisms, with no very evident relation to the nature of these latter. Thus the blue rays (of 477 $\mu\mu$) attract the protozoan infusorian *Euglena,* the hydroid cœlenterate *Eudendrium,* and the seedlings of oats; while the yellowish-green rays (of 534 $\mu\mu$) in turn affect the protozoan *Chlamydomonas,* the little water-flea *Daphnia* (crustacean), and the larvæ of barnacles (crustacea).

Aside from these heliotropic movements which they share with plants, animals show higher powers of individuality, of initiation, of

[6] Russell, Edward John, and Hutchinson, Henry Brougham, 1909, p. 118; 1913, pp. 191, 219.

[7] G. N. Calkins.

[8] Loeb, Jacques, and Wasteneys, Hardolph, 1915. 1, pp. 44–47; 1915. 2, pp. 328–330.

experiment, and of what Jennings cautiously terms "a conscious aspect of behavior." In his remarkable studies this author traces the genesis of animal behavior to reaction and trial. Thus the behavior of organisms is of such a character as to provide for its own development. Through the principle of the production of varied movements and that of the resolution of one physiological state into another, anything that is possible is tried and anything that turns out to be advantageous is held and made permanent.[9] Thus the sub-psychic stages when they evolve into the higher stages give us the rudiments of discrimination, of choice, of attention, of desire for food, of sensitiveness to pain, and also give us the foundation of the psychic properties of habit, of memory and of consciousness.[10] These profound and extremely ancient powers of animal life exert a constant *creative influence* on animal form, whether we adopt the Lamarckian or Darwinian explanation of the origin of animal form, or find elements of truth in both explanations.[11] Less cautious observers than Jennings[12] find in the Foraminifera the rudiments of the highest functions and the most intelligent behavior of which undifferentiated protoplasm has been found capable.

In the evolution of the Protozoa[13] the starting point is a simple cell consisting of a small mass of protoplasm containing a nucleus. This passes into the plasmodial condition of the Rhizopods, in which the protoplasm increases enormously to form the relatively large, unprotected masses adapted to the creeping or semi-terrestrial mode of life. From these evolve the forms specialized for the floating pelagic habit, namely, the Foraminifera and Radiolaria, protected by an excessive development and elaboration of their skeletal structures.[14] In the Mastigophora the body develops flagellate organs of locomotion and food-capture. As an offshoot from the ancestors of these forms arose the Ciliata, the most highly organized unicellular types of living beings, for a Ciliate like every other protozoan is a complete and independent organism and is specialized for each and all of the vital functions performed by the higher multicellular organisms as a whole.

In the chemical life of the Protozoa[15] (Amœba) the protoplasm is made up of colloidal and of crystalloidal substances of different density, between which there is a constant, orderly, chemical activity. The relative speed of these orderly processes is due to specific catalyzers which control each successive step in the long chain of chemical actions. Thus in the breaking down process (destructive metabolism) the by-

[9] Jennings, H. S., 1906, pp. 318, 319.

[10] *Op. cit.*, pp. 329–335.

[11] These rival theories are fully explained below in the introduction to the second lecture.

[12] Heron-Allen, Edward, 1915, p. 270.

[13] Minchin, E. A., 1916, p. 277.

[14] *Op. cit.*, p. 278.

[15] Calkins, Gary N., 1916, p. 260.

products act as poisons to other organisms or they may play an important part in the vital activities of the organism itself, as in the phosphorescence of *Noctiluca,* or as in reproduction and regeneration. Since regrowth or regeneration[16] takes place in artificially separated fragments of cells in which the nuclear substance (chromatin) is believed to be absent, the formation of new parts may be due to a specific enzyme, or perhaps to some chemical body analogous to hormones and formed as a result of mutual interaction of the nucleus and the protoplasm. Reproduction through cell-division is also interpreted theoretically as due to action set up by enzymes or other chemical bodies produced as a result of interaction of nucleus and cell body. The

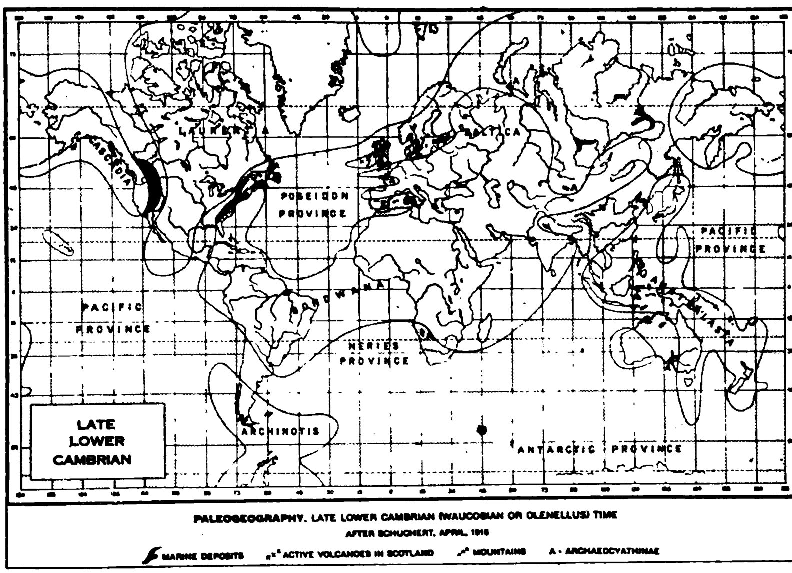

FIG. 1. THE WORLD IN LATE LOWER CAMBRIAN (WAUCOBIAN OR OLENELLUS) TIME. After Schuchert.

protoplasm is regenerated, including both the nuclei and the cell plasm, by the distribution of large quantities of nucleo-proteins, the specific chemical substance of chromatin.

Through this modern chemical interpretation of the Protozoan life cycle we may conceive how the three laws of thermodynamics may be applied to single-celled organisms, and especially our fundamental biologic law of action, reaction and interaction. By far the most difficult problem in biologic evolution is the working of this law among the many-celled organisms (Metazoa) including both invertebrates and vertebrates.

During the long period of pre-Cambrian time, which is estimated at not less than thirty million years from the actual thickness of the

[16] *Op. cit.,* pp. 261–264, 266.

Canadian pre-Cambrian rocks, some of the simpler protozoa gave rise to the next higher stage of animal evolution and to the adaptive radiation on land and sea of the Invertebrata. We are compelled to assume that the *physico-chemical actions, reactions and interactions* were sustained and rendered step by step more complex as the single cells passed into groups of cells, and these into organisms with two chief cell layers (Cœlenterata), and finally into organisms with three chief cell layers.

The metamorphosis of the pre-Cambrian rocks has for the most part concealed or destroyed all the life impressions which were undoubtedly made in the various continental or oceanic basins of sedimentation. Indirect evidences of the long process of life evolution are found in the great accumulations of limestone, and in the deposits of iron and graphite[17] which, as we have already observed, constitute certain proofs of the existence at enormously remote periods of limestone-forming algæ, of iron-forming bacteria and of a variety of chlorophyll-bearing plants. These evidences begin with the metamorphosed sedimentaries overlying the basal rocks of the primal earth's crust. The discovery by Walcott[18] of the highly specialized and differentiated invertebrates of the Middle Cambrian seas completely confirms the prophecy made by Charles Darwin in 1859[19] as to the great duration of pre-Cambrian time.

By Middle Cambrian time the adaptive radiation of the Invertebrata to all the conditions of life—in continental waters, along the shore lines, and in the littoral and pelagic environment of the seas—was governed by mechanical and chemical principles fundamentally similar to those observed among the protozoa, but distributed through myriads of cells and highly complicated tissues and organs, instead of being differentiated within a single cell as in the ciliate protozoa. Among the principal functions thus evolved were, first, a more complicated action, reaction and interaction with the environment and within the organism; second, a more efficient locomotion in the quest of food, in the capture of food and in the escape from enemies, giving rise in some cases to skeletal structures of various types; third, offensive and defensive armature and weapons, including chemical modes of offence and defence and methods of burrowing.[20] There are also protective coverings for sessile animals.

We find swiftly moving types with the lines of modern submarines, whose mechanical means of propulsion resemble those of the most primitive darting fishes (*e. g., Sagitta* and other chaetognaths). Other

[17] Barrell, Joseph. See Pirsson, Louis V., and Schuchert, Charles, 1915, p. 547.

[18] Walcott, Charles D., 1911, 1912.

[19] Darwin, Charles, 1859, pp. 306, 307.

[20] R. W. Miner.

types like the Crustacea have armature for the triple purposes of defence, offence, and locomotion; they are adapted to less swift motion and include the slowly-moving, bottom-living, armored types of trilobites. Then there are slowly moving fixed forms, such as the brachiopods and gastropods, with very dense armature of phosphate and carbonate of lime. Finally, there are pelagic or floating types such as the jelly fishes which are chemically protected by the poisonous secretions of their "sting-cells."

There is abundant evidence that in pre-Cambrian time certain of the invertebrates had already passed through primary, secondary, and even tertiary phases of adaptation.

Our first actual knowledge of such adaptations dates back to the pre-Cambrian and is afforded by Walcott's discovery[21] in the Greyson shales of the Algonkian Belt Series of fragmentary remains of that problematic fossil, *Beltina danai,* which he refers to the Merestomata and near to the Eurypterids, thus making it probable that either Eurypterids, or forms ancestral both to trilobites and Eurypterids existed in pre-Cambrian times. More extensive adaptive radiations are found in the Lower Cambrian life zone of *Olenellus,* a compound phase of trilobite evolution representing the highest trilobite development. These animals are beautifully preserved as fossils because of their dense chitinous armature which protected them and at the same time admitted of considerable freedom of motion. The relationships of these animals have long been in dispute, but the discovery of the ventral surface and appendages in the Mid-Cambrian *Neolenus serratus* seems to place the trilobites definitely as a sub-class of the Crustacea, with affinities to the existing freely swimming, pelagic phyllopods.

FIG. 2. A MID-CAMBRIAN TRILOBITE, *Neolenus serratus* (ROMINGER). After Walcott.

A most significant biological fact is that primitively armored and sessile brachiopods of the Cambrian seas have remained almost unchanged generically to the present time, namely, for a period of nearly thirty million years. These animals afford a classic illustration of the rather exceptional condition known to evolutionists as "balance," resulting in absolute stability of type. One example is found in *Lingulella (Lingula)*, of which the fossil form, *Lingulella acuminata,* characteristic of Cambrian and Ordovician times, is closely similar to

21 Walcott, Charles D., 1899, pp. 235–244.

that of *Lingula anatina,* a species living to-day. Representatives of the genus *Lingula* (*Lingulella*) have persisted from Cambrian to recent times. The great antiquity of the Brachiopods as a group is well illustrated by the persistence of *Lingula* (Cambrian—Ordovician—Recent), on the one hand, and of *Terebratula* (Devonian—Recent), belonging to a widely differing family, on the other. These lamp-shells are thus characteristic of all geologic ages, including the present. Reaching their maximum radiation during the Ordovician and Silurian, they gradually lost their importance during the Devonian and Permian, and at the present time have dwindled into a relatively insignificant group, members of which range from the oceanic shore-line to the deep-sea or abyssal habitat.

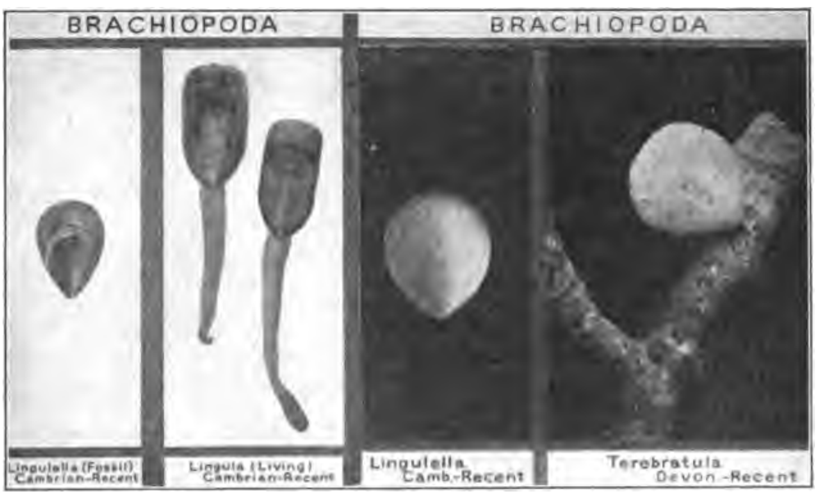

FIG. 3. BRACHIOPODS, CAMBRIAN AND RECENT. *Lingulella* (*Lingula*) *acuminata,* ranging from Cambrian to Ordovician, and the very similar *Lingula anatina,* persisting from Cambrian times down to the present day. *Lingulella,* Cambrian to Ordovician, contrasted with the widely differing *Terebratula* which ranges from Devonian to recent times.

By the Middle Cambrian the continental seas covered the whole region of the present Cordilleras of the Pacific coast. In the present region of Mount Stephen, B. C., in the unusually favorable marine oily shales of the Burgess formation, the remarkable evolution of invertebrate life prior to Cambrian time has been revealed through Walcott's epoch-making discoveries between 1909 and 1912.[22] It is at once evident (Figs. 2–9) that the seashore and pelagic life of this time exhibits types as widely divergent as those which now occur among the aquatic Invertebrata. Not only are the characteristic external features of these soft-bodied invertebrates evident in the fossil remains, but in some cases even the internal organs show through the imprint of the

[22] Walcott, Charles D., 1911, 1912.

transparent integument. Walcott's researches on this superb series have brought out two important points: first, the great antiquity of the chief invertebrate groups and their high degree of specialization in Early Cambrian times, which makes it necessary to look for their origin far back in the pre-Cambrian ages; and, second, the extraordinary per-

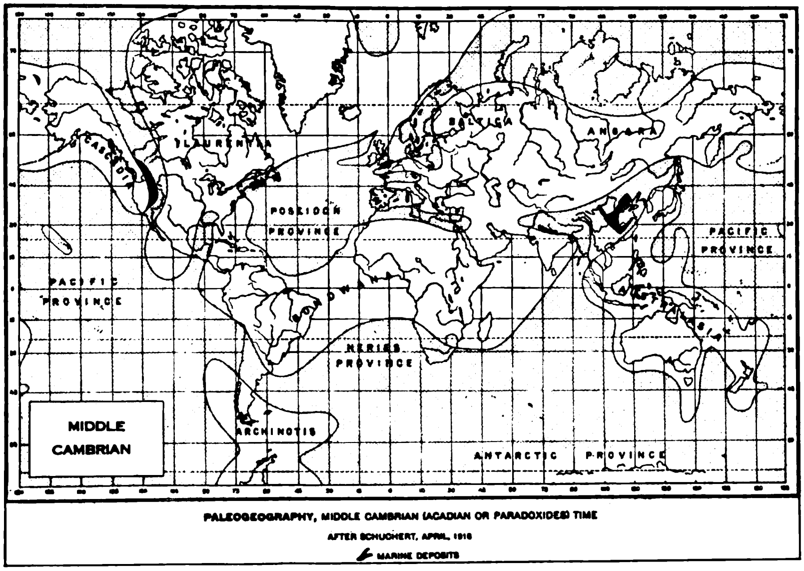

FIG. 4. THE WORLD IN MIDDLE CAMBRIAN (ACADIAN OR PARADOXIDES) TIME. After Schuchert.

sistence of type among members of all the invertebrate phyla from the Mid-Cambrian to the present time, so that sea-forms with an antiquity of 25 million years can be placed side by side with existing sea-forms with very obvious similarities of function and structure as in the series arranged for these lectures by Mr. Roy W. Miner, of the American Museum of Natural History.

Except for the trilobites, the existence of Crustacea in Cambrian times was unknown until the discovery of the primitive shrimp-like form, *Burgessia bella* (Fig. 5), a true crustacean, which may be compared with *Apus lucasanus,* a member of the most nearly allied recent group. We observe a close correspondence in the shape of the chitinous shield (carapace), in the arrangement of the leaf-like locomotor appendages at the base of the tail, and in the clear internal impressions in *Burgessia* of the so-called "kidneys" with their branched tubules. The position of these organs in *Apus* is indicated by the two light areas on the carapace. Other specimens of *Burgessia* found by Walcott show that the tapering abdominal region and tail are jointed as in *Apus.*

The age of the armored merostome arthropods is also thrust back to Mid-Cambrian times by the discovery of several genera of Aglas-

pidæ, the typical species of which, *Molaria spinifera* Walcott, may be compared with that "living fossil" the horseshoe crab (*Limulus polyphemus*), its nearest modern relative, which is believed to be not so closely related to the phyllopod crustaceans as would at first appear, but rather to the Arachnida through the Eurypterids and scorpions. *Molaria* and *Limulus* are strikingly similar in their cephalic shield, segmentation, and telson; but the latter shows an advance upon the earlier type in the coalescence of the abdominal segments into a single abdominal shield-plate. The trilobate character of the cephalic shield in *Molaria* is an indication of its trilobite affinities; hence we apparently have good reason to refer both the merostomes and phyllopods to an ancestral trilobite stock.

FIG. 5. SHRIMP AND HORSE-SHOE CRAB OF THE CAMBRIAN. *Burgessia bella*, a shrimp-like crustacean of the Middle Cambrian (after Walcott) compared with the very similar *Apus lucasanus* of recent times; and *Molaria spinifera*, a Mid-Cambrian merostome (after Walcott) compared with the "horse-shoe crab," *Limulus polyphemus*.

Another mode of defence is presented by the sessile, rock-clinging sea-cucumbers (Holothuroidea) protected by their leathery epidermis in which are scattered a number of calcareous plates, as among certain members of the modern edentate mammals. Fossils of this group have been known heretofore only through scattered spicules and calcareous plates dating back no earlier than Carboniferous times (Goodrich); therefore Walcott's holothurian material from the Cambrian constitutes new records for invertebrate paleontology, not only for the preservation of the soft parts, but for the great antiquity of these Cambrian strata. In *Louisella pedunculata* (Fig. 6) we observe the preservation of a double row of tube-feet, and the indication at the top of oral tentacles around the mouth like those of the modern Elpidiidæ. A typical rock-clinging holothurian is the recent *Pentacta frondosa*.

Beside these sessile, rock-clinging forms, the adaptive radiation of the holothurians developed burrowing or fossorial types, an example of which is the Mid-Cambrian *Mackenzia costalis* (Fig. 6) which strikingly suggests one of the existing burrowing sea-cucumbers, *Synapta*

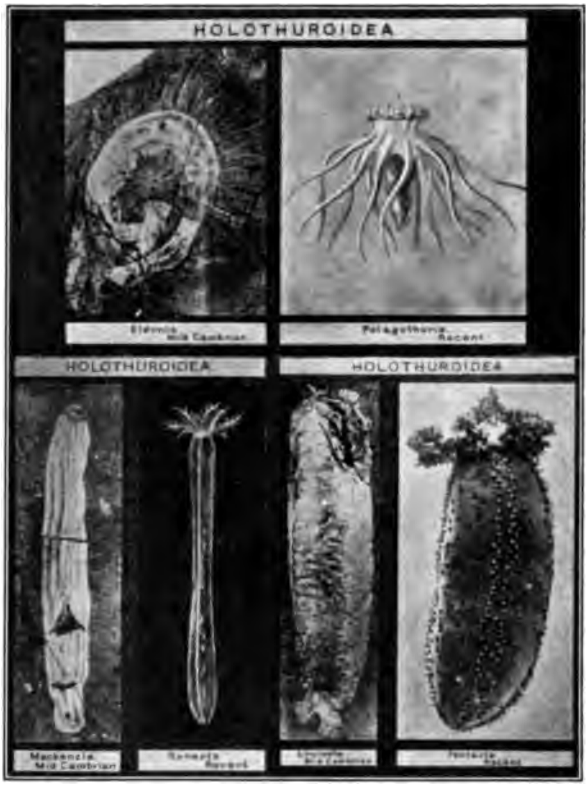

FIG. 6. SEA-CUCUMBERS AND JELLY FISH OF THE CAMBRIAN. *Eldonia ludwigi* of the Middle Cambrian (after Walcott), regarded as pelagic, strongly resembles the jelly fish. *Pelagothuria natatrix*, thought to be an analogous form, shows wide differences. The mouth of *Pelagothuria* is above the swimming umbrella, the posterior part of the body and the anal opening are below: in the fossil *Eldonia* both mouth and anus hang below. *Mackenzia costalis*, a Mid-Cambrian form (after Walcott) strongly resembling the burrowing sea-cucumbers, one form of which, *Synapta girardii*, is shown at the right. *Louisella pedunculata*, another Mid-Cambrian form (after Walcott), and a recent rock-clinging form, *Pentacta frondosa*.

girardii. The characteristic elongated cylindrical body-form with longitudinal muscle-bands is clearly preserved in the fossil, while around the mouth is a ring of tubercles interpreted by Walcott as calcareous ossicles from above which the oral tentacles have been torn away.

A remarkable and problematic Mid-Cambrian fossil, *Eldonia ludwigi* (Fig. 6), is regarded by Walcott as a free-swimming or pelagic animal. It bears a superficial resemblance to a medusa or jelly fish, while the lines radiating from a central ring suggest the existence of

a water vascular system; but the cylindrical body coiled around the center shows a spiral intestine through its transparent body-wall, and it is therefore considered to be a swimming holothurian or sea-cucumber with a medusa-like umbrella. The existing holothuroid *Pelagothuria natatrix* Ludwig, shown at the right, is somewhat analogous although it also displays wide differences of structure. If *Eldonia ludwigi* proves to be a holothurian we witness in Mid-Cambrian strata members of this order differentiated into at least three widely distinct families.

The worms, including swimming and burrowing annulates, are represented in the Burgess fauna by a very large number of specimens, comprising nineteen species, distributed through eleven genera and six families. Most of these are of the order Polychæta, as, for example, *Worthenella cambria,* in which the head is armed with tentacles, while the segmented body and the continuous series of bilobed parapodia are very clear. When compared with such typical living polychætes as *Nereis virens* and *Arabella opalina* (Fig. 7), we have clear proof of the modern relationships of these Mid-Cambrian species, as well as of Cam-

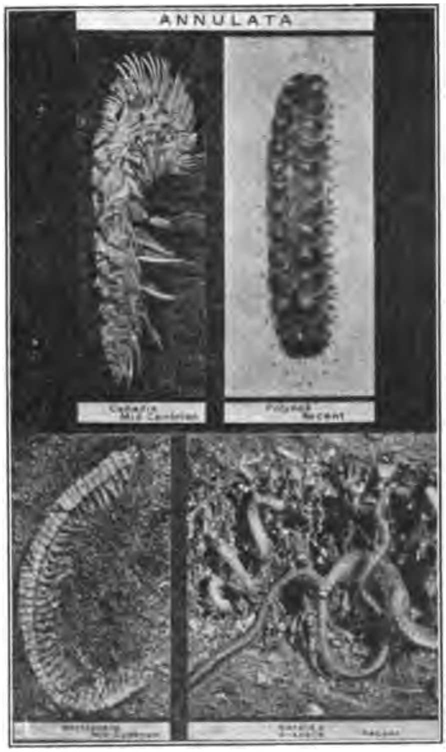

FIG. 7. WORMS (*Annulata*) OF THE MIDDLE CAMBRIAN. *Cancdia spinosa,* a Mid-Cambrian form (after Walcott) with overlapping groups of scale-like dorsal spines, resembling those of the living *Aphroditidæ,* such as *Polynoe squamata* *Worthenella Cambric* a worm of Mid-Cambrian times (after Walcott) compared with *Nereis virens* and *Arabella opalina,* reecnt marine worms.

FIG. 8. FREELY SWIMMING CHÆTOGNATHS. *Amiskwia sagittiformis,* a Mid-Cambrian form (after Walcott), has a body divided into head, trunk and tail like the recent *Sagitta,* as seen in *S. gardineri.*

brian sea-shore and tidal conditions closely similar to those of the present time. A specialization toward the spiny or scaly annulates at this period is emphasized in such forms as *Canadia spinosa* (Fig. 7), a slowly-moving form which shows a development of lateral chetæ and overlapping groups of scale-like dorsal spines comparable only to those of the living Aphroditidæ. An example of this latter family is *Polynoe squamata,* furnished with dorsal scales. Still other recent forms, such as *Palmyra aurifera* Savigny, have groups of spinous scales closely resembling those of *Canadia.*

Even the modern freely propelled *Chætognatha* have their representatives in the Mid-Cambrian, for to no other group of invertebrates can *Amiskwia sagittiformis* Walcott (Fig. 8) be referred, so far as we can judge by its external form. As in the recent *Sagitta* the body is divided into head, trunk, and a somewhat fish-like tail. Its single pair of fins of chætognath type would perhaps give a clearer affinity to the genus *Spadella.* The conspicuous pair of tentacles which surmounts the head is absent in modern chætognaths, although some recent species show a pair of sensory papillæ mounted on a stalk on either side of the head as in *Spadella cephaloptera* Bush. The digestive canal and other digestive organs appear through the thin walls of the body.

FIG. 9. JELLY FISH (*Scyphomedusæ*) OF THE CAMBRIAN. *Peytoia nathorsti,* Mid-Cambrian (after Walcott), and *Dactylometra quinquecirra,* recent. The thirty-two lobes of the fossil specimen correspond with the same number often observed in *Dactylometra,* and the characteristic marginal tentacles may have been lost in *Peytoia.*

A modern group of jelly fishes, the Scyphomedusæ (Fig. 9), is represented by the Middle Cambrian *Peytoia nathorsti* the elliptical disc of which is seen from below. Although this fossil species is ascribed by Walcott to the group Rhizostomæ because of a lack of marginal tentacles, the thirty-two radiating lobes which are so beautifully preserved in the fossil correspond closely with those of the existing genus *Dactylometra.* It is possible that the marginal tentacles may have been lost in *Peytoia,* as so frequently happens in living jelly fishes when in a dying condition.

PHYLA OF FOSSIL INVERTEBRATA

Protozoa,	Echinodermata,
Coelenterata,	Annulata,
Molluscoida,	Arthropoda,
	Mollusca.

From the Burgess fauna it appears that the invertebrates had entered all the life zones of the continental and oceanic waters except possibly the abyssal. All the principal phyla—the segmented Annulata, the joined Arthropoda (including trilobites, merostomes, crus-

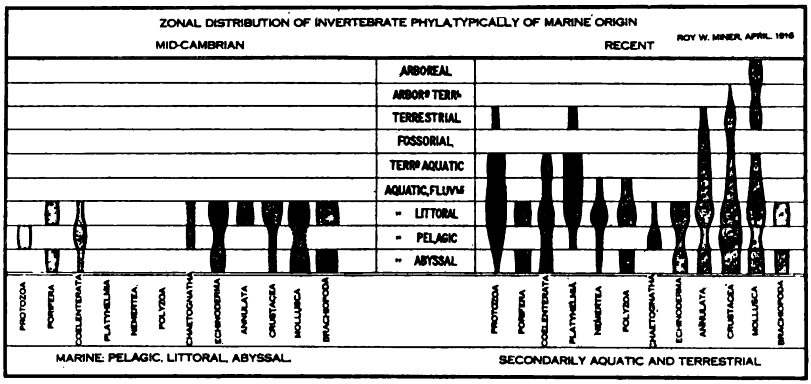

FIG. 10. LIFE ZONES OF CAMBRIAN AND RELATED EXISTING INVERTEBRATES. Chart showing the contrast between the Mid-Cambrian (left) and recent (right) phyla of the Invertebrata. By Roy W. Miner.

taceans, arachnids, and insects), medusæ and other cœlenterates, echinoderms, brachiopods, molluscs (including pelycypods, gastropods, ammonites and other cephalopods), and sponges—were all clearly established in pre-Cambrian times. Which one of these great invertebrate

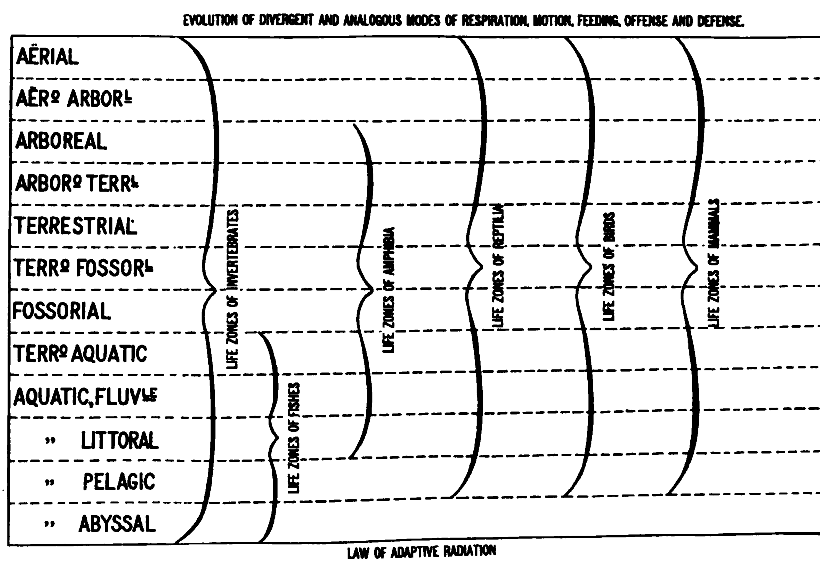

FIG. 11. LIFE ZONES OF INVERTEBRATES, COMPARED WITH THOSE OF FISHES, AMPHIBIANS, REPTILES, BIRDS AND MAMMALS. Chart showing the extension of vertebrates and invertebrates throughout the various habitat zones.

brian sea-shore and tidal conditions closely similar to those of the present time. A specialization toward the spiny or scaly annulates at this period is emphasized in such forms as *Canadia spinosa* (Fig. 7), a slowly-moving form which shows a development of lateral chetæ and overlapping groups of scale-like dorsal spines comparable only to those of the living Aphroditidæ. An example of this latter family is *Polynoe squamata,* furnished with dorsal scales. Still other recent forms, such as *Palmyra aurifera* Savigny, have groups of spinous scales closely resembling those of *Canadia.*

Even the modern freely propelled *Chætognatha* have their representatives in the Mid-Cambrian, for to no other group of invertebrates can *Amiskwia sagittiformis* Walcott (Fig. 8) be referred, so far as we can judge by its external form. As in the recent *Sagitta* the body is divided into head, trunk, and a somewhat fish-like tail. Its single pair of fins of chætognath type would perhaps give a clearer affinity to the genus *Spadella.* The conspicuous pair of tentacles which surmounts the head is absent in modern chætognaths, although some recent species show a pair of sensory papillæ mounted on a stalk on either side of the head as in *Spadella cephaloptera* Bush. The digestive canal and other digestive organs appear through the thin walls of the body.

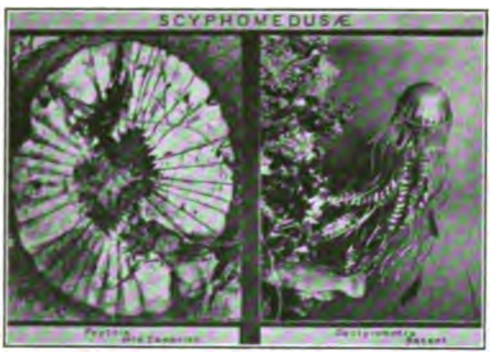

FIG. 9. JELLY FISH (*Scyphomedusæ*) OF THE CAMBRIAN. *Peytoia nathorsti,* Mid-Cambrian (after Walcott), and *Dactylometra quinquecirra,* recent. The thirty-two lobes of the fossil specimen correspond with the same number often observed in *Dactylometra,* and the characteristic marginal tentacles may have been lost in *Peytoia.*

A modern group of jelly fishes, the Scyphomedusæ (Fig. 9), is represented by the Middle Cambrian *Peytoia nathorsti* the elliptical disc of which is seen from below. Although this fossil species is ascribed by Walcott to the group Rhizostomæ because of a lack of marginal tentacles, the thirty-two radiating lobes which are so beautifully preserved in the fossil correspond closely with those of the existing genus *Dactylometra.* It is possible that the marginal tentacles may have been lost in *Peytoia,* as so frequently happens in living jelly fishes when in a dying condition.

PHYLA OF FOSSIL INVERTEBRATA

Protozoa,	Echinodermata,
Coelenterata,	Annulata,
Molluscoida,	Arthropoda,
	Mollusca.

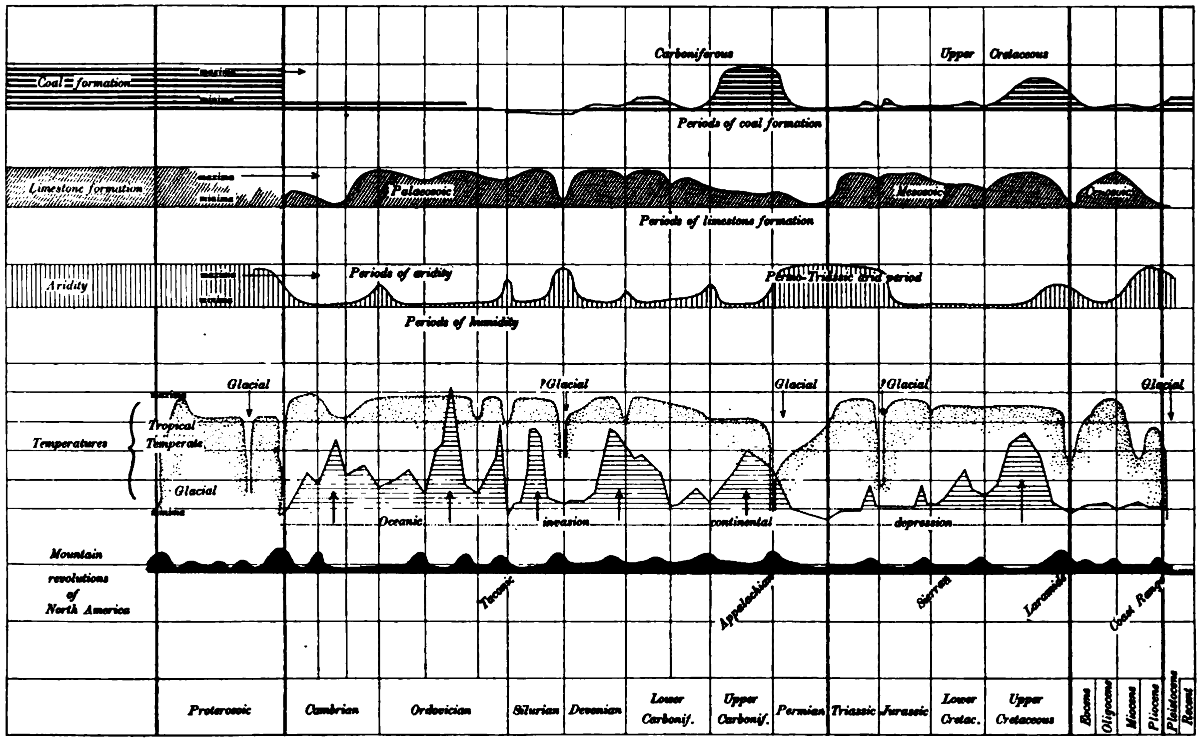

FIG. 13. CORRELATION OF CLIMATIC, CONTINENTAL, OCEANIC AND LIFE PHASES modified from Huntington after Schuchert, showing the maximum and minimum periods of coal formation, of limestone formation, of aridity and of humidity, and also five theoretic epochs of glaciation in the northern and southern hemispheres, seven periods of maximum continental depression and oceanic invasion, and six periods of mountain revolution.

other true Crustacea of the Cambrian, and to the cirripedes or barnacles of the Ordovician.

Schuchert observes that there is no more significant period in the history of the world than the Devonian[24] (Fig. 12) for at this time the increasing verdure of the land invited the invasion of life from the waters, the first conquest of the terrestrial environment being attained

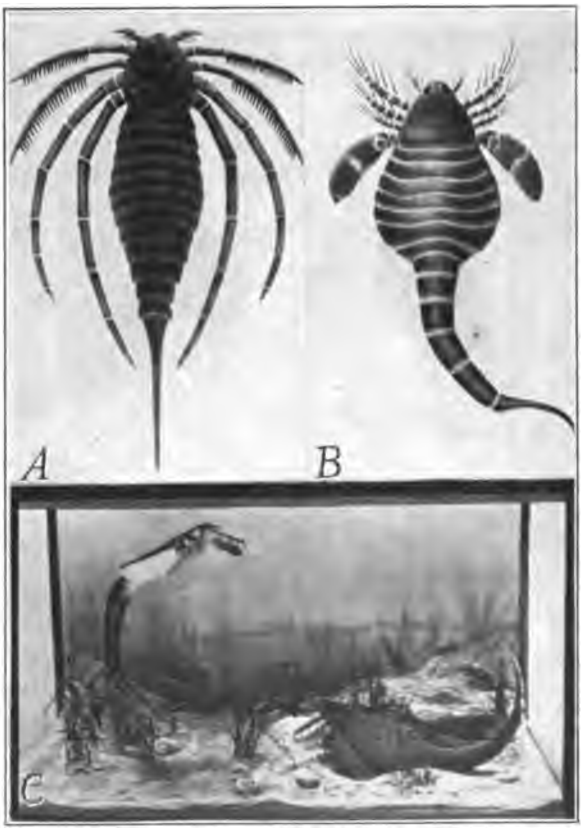

FIG. 14. *A.* RESTORATION OF *Stylonurus excelsior*, CATSKILL SANDSTONE. Natural length, four feet. *B.* Restoration of *Eusarcus*, Bertie waterlime. Natural length, three feet. *C.* Restoration of the Silurian eurypterid *Eusarcus*, age of the Bertie waterlime. After John M. Clarke.

by the scorpions, shell fish, worms and insects. This is an instance of the constant dispersion of animal forms into new environments for their food supply, the chief instinctive cause of all migration. This impulse is constantly acting and reacting throughout geologic time with the migration of the environment, graphically presented by Huntington's chart from the researches of Barrell, Schuchert, and others (Fig. 13, Huntington's chart). The periodic readjustment of the

24 Pirsson, Louis V., and Schuchert, Charles, 1915, p. 714.

earth crust of North America[25] is witnessed in fourteen periods of mountain-making of varying importance. Between these relatively short periods of upheaval came[26] periods when the continent was more or less flooded by the oceans. There are certainly twelve and probably not less than seventeen periods of continental flooding which vary in extent up to the submergence of four million square miles of surface. Each of these changes, which by some geologists are believed to be cyclic, included long epochs especially favorable to certain forms of life, resulting in the majority of cases in high specialization like that of the sea-scorpions (Eurypterids) followed by more or less sudden extinction.

Changes of environment play so large and conspicuous a part in the selection and elimination of the invertebrates that the assertion is often made that environment is the cause of evolution, a statement directly contrary to our fundamental biologic law that the cause of evolution lies within the four complexes of action, reaction and interaction (see p. 10). Perrin Smith, who has made a most exhaustive analysis of the evolution of the cephalopod molluscs and especially of the Triassic ammonites, observes that the evolution of form continues uninterruptedly even where there is no evidence whatever of environmental change.

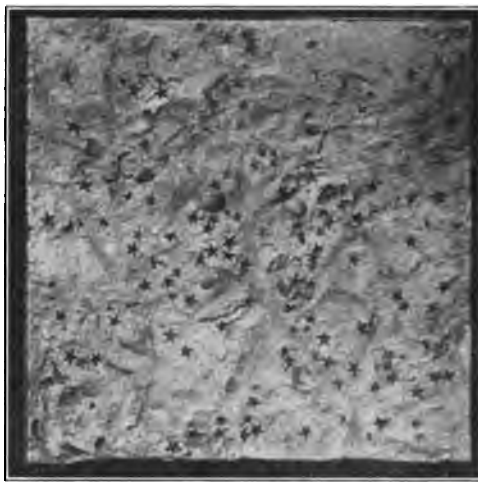

FIG. 15. A FOSSIL STAR-FISH OF DEVONIAN TIMES, ASSOCIATED WITH AND DEVOURING BIVALVES. Hamilton group, Saugerties, New York. After John M. Clarke.

It was in the ammonites that Waagen first observed the actual mode of transformation of one animal form into another, set forth in his classic paper of 1869, "Die Formenreihe des *Ammonites subradiatus*."[27] The essential feature of the "mutation of Waagen"[28] is that it established the law of minute and inconspicuous changes of form which accumulate so gradually that they are observable only after a

25 Pirsson, Louis V., and Schuchert, Charles, 1915, p. 979.

26 *Op. cit.*, p. 982.

27 Waagen, W., 1869.

28 The term "mutation" was introduced by Waagen in 1869. Twenty years later the great Austrian paleontologist, Neumayr, defined the "Mutationsrichtung" as the tendency of form to evolve in certain definite directions. See Neumayr, M., 1889, pp. 60, 61.

considerable passage of time; they take a definite direction (*Mutationsrichtung*) and represent a true evolution of the chromatin. This law of definitely directed evolution is illustrated in the detailed structure of the type series of ammonites (Fig. 16) in which Waagen's discovery was made. It has proved to be a fundamental law of the evolu-

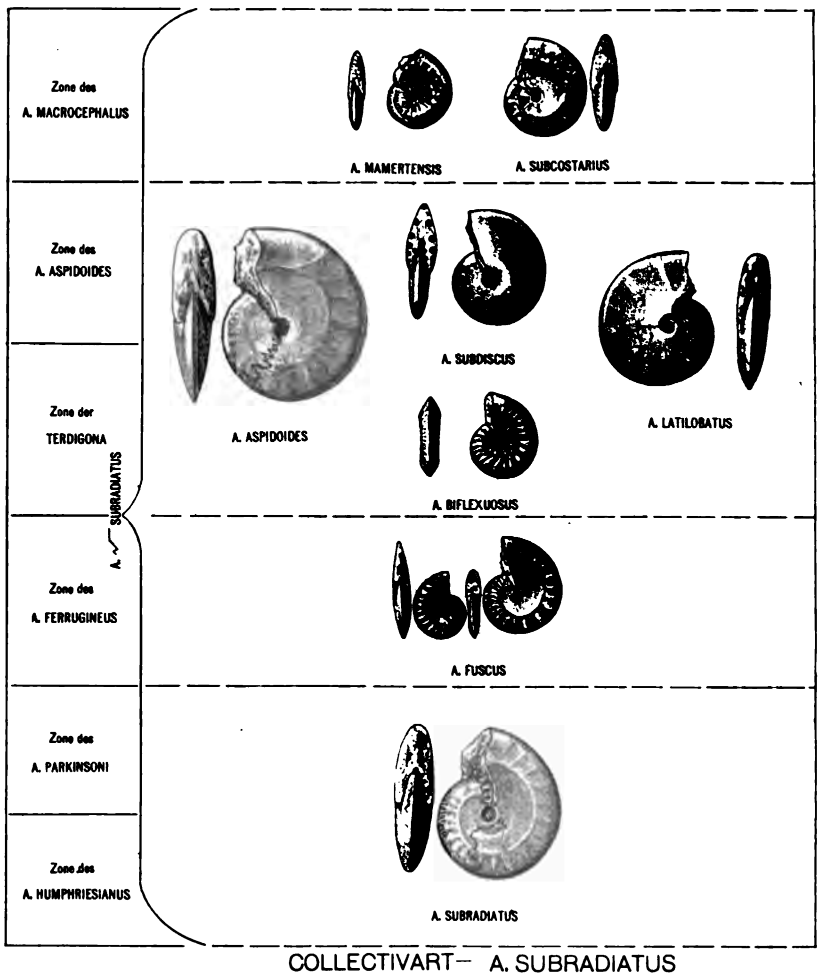

FIG. 16. THE TYPE SERIES OF THE MUTATIONS OF WAAGEN (1869) IN AMMONITES. Successive mutations of *Ammonites subradiatus* drawn and rearranged from the original plates of Waagen.

tion of form, for it is observed alike in invertebrates and vertebrates wherever a closely successive series can be obtained. In the invertebrates a mutation series of the brachiopod, *Spirifer mucronatus* of the Middle Devonian or Hamilton time, is one of the most typical (Fig. 17). The essential principle of Waagen's discovery, which is one of the most important in the whole history of biology, is that certain new char-

acters arise definitely and continuously, and, as Osborn has subsequently shown, adaptively.[29] It is unfortunate that the same term, "mutation," was chosen by de Vries to express his observation that

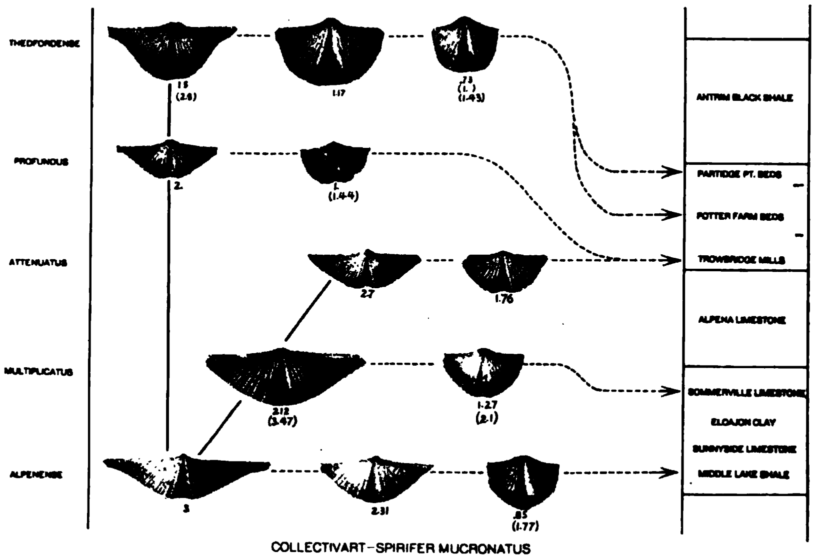

FIG. 17. SUCCESSIVE MUTATIONS OF *Spirifer mucronatus*. Specimens from the Alpena section arranged by Grabau. In the scale of strata at the right 8¼ mm. = 100 ft. depth.

certain characters in plants arise discontinuously through changes in the chromatin and without any definite direction or adaptive trend. The essential feature of de Vries's observations, in contrast to Waagen's, is that of discontinuous saltations either in indefinite or non-adaptive directions.

(*To be continued*)

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[29] Osborn, Henry Fairfield, 1912.

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THE DEVELOPMENT OF FOLK-TALES AND MYTHS[1]

By Dr. FRANZ BOAS

COLUMBIA UNIVERSITY

THE collections of folk-tales and myths of all continents, but particularly of North America, that have been accumulated during the last few decades, have yielded the definite result that the incidents of tales have a very wide distribution, that they have been carried from tribe to tribe, even from continent to continent, and have been assimilated to such an extent that rarely only there is any internal evidence that would indicate what is of native and what of foreign origin.

Although these incidents have a wide distribution, they have developed characteristic peculiarities in restricted parts of the territory in which they occur. I will illustrate this by means of some examples selected from among the folk-tales of the north Pacific coast of America.

An excellent illustration is presented by the North American tale of the Bungling Host. The fundamental idea of the story, the failure of the attempt to imitate magical methods of procuring food, is common to the whole North American Continent, apparently with the sole exception of California and of the Arctic coast. The incidents, however, show considerable variation. Confined to the north Pacific coast are the tricks of letting oil drip from the hands, of obtaining fishroe by striking the ankle, and of letting berries ripen by the song of a bird. The widely spread trick of cutting or digging meat out of the host's body is practically unknown on the north Pacific coast. The host's trick of killing his children, who revive, which forms part of the Bungling Host tale in the state of Washington and on the Plateaus, is well known on the north Pacific coast. However, it does not occur as part of this story. It is entirely confined to stories of visits to the countries of supernatural beings.

Similar observations may be made in regard to the prolific test theme. The dangerous entrance to the house of the supernatural beings is represented among the northern tribes of the north Pacific coast by the closing cave or by the closing horizon; among the tribes farther to the south, by a snapping door; on the western plateaus, by animals that watch the door of the house. Heat tests occur frequently, but in some regions the heat is applied by baking the youth in an

[1] Based on an investigation of the mythology of the Tsimshian, to be pub lished in the Annual Report of the Bureau of American Ethnology.

oven or boiling him in a kettle; in others by sending him into an overheated sweat-lodge or placing him near a large fire. More important differences may be observed in the general setting of the test tales, which in some areas are tests of the son-in-law; in others, matches between the inhabitants of a village and their visitors.

Other examples of the local development of the plot of a story by the introduction of specific incidents occur, as in the north Pacific coast story of raven killing the deer, whom, according to the Alaskan tale, he strikes with a hammer, while in the more southern form he pushes him over a precipice. Similarly, in a story of a rejected lover who is made beautiful by a supernatural being the magic transformation is accomplished in the northern versions by bathing the youth in the bathtub of the supernatural being, while in the south he is given a new head.

In other cases the geographical differentiation of the tales is not quite so evident, because different types of stories overlap. This is the case in the widely spread story of the deserted child. Tales in which a youth gives offense by being lazy or by wasting food belong to Alaska. Another tpe, in which a girl is deserted because she has married a dog, belongs to British Columbia; but the two types overlap in distribution. This particular theme occurs in a much wider area on the American Continent, and other types may easily be recognized in the stories of the Plains Indians.

Tales of marriages with supernatural beings or animals are often found in the form of the abduction of a girl who has unwittingly offended an animal. This type seems to belong primarily to Alaska, while the theme of helpful animals that succor unfortunate and innocent sufferers is much more frequent among the tribes of British Columbia.

All these examples illustrate that there are a number of simple plots, which have a wide distribution, and which are elaborated by a number of incidents that must be interpreted as literary devices peculiar to each area. In all these cases the incidents obtain their peculiar significance by being worked into different plots.

On the other hand, we find also certain incidents that have a very wide distribution and occur in a variety of plots. Many examples of these are given in the annotations to all the more important recent collections of folk-tales. The local character of folk-tales is largely determined by typical associations between incidents and definite plots.

In most of the cases here discussed the plot has a general human character, so that the processes of invention and diffusion of plots must be looked at from a point of view entirely different from that to be applied in the study of invention and diffusion of incidents. The latter are, on the whole, fantastic modifications of every-day

experiences, and not likely to develop independently with a frequency sufficient to explain their numerous occurrences over a large area. On the other hand, the stories of a deserted child, of contests between two villages, of a rejected lover, and other similar ones, are so closely related to every-day experiences, and conform to them so strictly, that the conditions for the rise of such a framework of literary composition are readily given. Nevertheless the plots that are characteristic of various areas should be studied from the point of view of their literary characteristics and of their relation to the actual life of the people.

An attempt of this kind has been made by Dr. John R. Swanton,[2] who enumerates a number of formulas of tales of the north Pacific coast. In this area the following plots occur a number of times:

1. A woman marries an animal, is maltreated by it, and escapes.

2. A woman marries an animal, who pities and helps her; she returns with gifts.

3. Men or women marry animals and receive gifts; crest stories.

4. Men obtain crests through adventures in hunting or traveling.

5. Parents lose their children; a new child is born owing to the help of some supernatural being; adventures of this child.

6. A man maltreats his wife, who receives help from supernatural beings.

7. The adventures of hunters; they meet dangers, which the youngest or oldest one overcomes.

8. War between two tribes, due to the seduction of a woman and the murder of her lover.

All these stories show a unity of the underlying idea. They are built up on some simple event that is characteristic of the social life of the people and that stirs the emotion of the hearers. Some tales of this type are elaborated in great detail, and therefore conform to our own literary standards. To this class belongs, for instance, the tale of a deserted prince. It is told that a prince fed eagles instead of catching salmon. In winter when food was scarce he was deserted by his relatives, but was helped by the eagles, who gave him food. It is told in great detail how larger and larger animals were sent to him. When the prince had become rich he sent some food to the only person who had taken pity on him. By chance his good luck was discovered and he rescued the tribe that was starving and married the chief's daughter.

Another tale of this kind is "Growing-up-like-one-who-has-a-grandmother." This is a tale of another poor boy who is helped by a supernatural being, overcomes all the young men of the village in various

[2] John R. Swanton, "Types of Haida and Tlingit Myths," *American Anthropologist*, N. S., Vol. VII., 1905, p. 94.

contests, and thus obtains the right to marry the chief's daughter. The chief feels humiliated, deserts him, and the youth kills a lake monster. When wearing its skin he is able to kill sea game, but finally is unable to take off the skin and must remain in the sea.

Besides these, there are a large number of complex tales of fixed form, which are put together very loosely. There is no unity of plot, but the story consists of the adventures of a single person. I do not refer here to the disconnected anecdotes that are told of some favorite hero, such as we find in the Raven legend or in the Transformer tales, but of adventures that form a fixed sequence and are always told as one story. Examples of this kind are quite numerous.

It is noticeable that only a few of the complex tales of the last-named type are known to several tribes. Although enough versions have been recorded to show that in each area the connection between the component parts of the story is firm, the whole complex does not migrate over any considerable distance. On the contrary, the parts of the tale have the tendency to appear in different connections. This point is illustrated, for instance, by the story of a man who is deserted on a sea-lion rock and is taken into the house of the wounded sea-lions whom he cures. This story appears in quite different connections in various regions. Other examples of similar kind are quite numerous.

The literary device that holds together each one of these tales consists in the use of the interest in the hero that has been created by the introductory story, and that makes the audience desirous of knowing about his further deeds and adventures. The greater the personal interest in the hero, the more marked is the desire to attach to his name some of the favorite exploits that form the subject of folk-tales. I presume this is the reason why in so many cases the introductory tales differ enormously, while the adventures and exploits themselves show a much greater degree of uniformity. This happens particularly in the case of tales of culture heroes. When a large number of the same exploits is thus ascribed to the heroes of different tribes, it seems to happen easily that the heroes are identified. Therefore I imagine that the steps in the development of a culture-hero myth may have been in many cases the following: An interesting story told of some personage; striking and important exploits ascribed to him; similar tales of these personages occurring among various tribes; identification of the heroes of different tribes. While I do not assume that this line of development has occurred every single time—and it seems to me rather plausible that in other cases the introductory story and the adventures may have come to be associated in other ways—it may be considered as proved that introduction and adventures do not belong together by origin, but are results of later association. The great diversity of associations of this type compels us to take this point of view.

On the whole, in many forms of primitive literature, the interest in the personality of the hero is a sufficient means of establishing and maintaining these connections. Nevertheless there are a few cases at least in which the adventures conform to a certain definite character of the hero. This is the case in northwestern America in the Raven, Mink, and Coyote tales, in which greed, amorous propensities, and vaingloriousness are the chief characteristics of the three heroes. In tales that have a more human background these tendencies are hardly ever developed.

The recorded material shows also that the imagination of primitive man revels in the development of certain definite themes, that are determined by the character of the hero, or that lend themselves in other ways to variation. Thus in Alaskan tales Raven's voraciousness, that induces him to cheat people and to steal their provisions, is an ever-recurring theme, the point of which is regularly the attempt to induce the people to run away and leave their property. Mink's amorousness has led to the development of a long series of tales referring to his marriages, all of which are of the same type. The strong influence of a pattern of thought on the imagination of the people is also illustrated by tales of marriages between animals and men or women and a few other types to which I referred before.

The artistic impulses of a people are not always satisfied with the loose connections of stories, brought about by the individuality of the hero, or strengthened by the selection of certain traits of his character illustrated by the component anecdotes. We find a number of cases in which a psychological connection of the elements of the complex story is sought. An example of this kind is found in the Raven legend of British Columbia, in which a number of unrelated incidents are welded into the form of an articulate whole. The adventures of the Steelhead Salmon, the Grizzly Bear, and Cormorant, are thus worked into a connected series. Raven kills Steelhead Salmon because he wants to use it to deceive Grizzly Bear. He holds part of the salmon in front of his body, so as to make the Bear believe that he has cut himself. Thus he induces the Bear to imitate him and to kill himself. Finally he tears out the tongue of Cormorant, who had witnessed the procedure, so that he may not tell. Another excellent case from the same region is the story of Raven's son and Thunderbird. Raven has seduced a girl, and their son is stolen by Thunderbird. In order to take revenge, he makes a whale of wood, then kills Pitch in order to calk the whale, and by its means drowns the Thunderbird. Among other tribes the same tale occurs in another connection. The animals have a game, and Thunderbird wins. The defeated guests are invited, and the host's wife produces berries by her song. Then the Thunderbird abducts her, and the revenge of the animals by means

of the whale follows. In the former group of tales the incident describing the death of Pitch is brought in, which ordinarily occurs as an independent story.

In these cases we find the same incidents in various connections, and this makes it clear that it would be quite arbitrary to assume that the incident developed as part of one story and was transferred to another one. We must infer that the elements were independent and have been combined in various ways. There certainly is nothing to prove that the connection in which an incident occurs in one story is older and nearer to the original form than one in which it occurs in another story.

The distribution of plots and incidents of North American folklore presents a strong contrast when compared to that found in Europe. European folk-tales, while differing in diction and local coloring, exhibit remarkable uniformity of contents. Incidents, plots, and arrangement are very much alike over a wide territory. The incidents of American lore are hardly less widely distributed; but the make-up of the stories exhibits much wider divergence, corresponding to the greater diversification of cultural types. It is evident that the integration of European cultural types has progressed much further during the last two or three thousand years than that of the American types. Cultural contrasts like those between the Northwest coast and the Plateaus, or between the Great Plains and the arid Southwest, are not easily found in Europe. Excepting a few of the most outlying regions, there is a great underlying uniformity in material culture, social organization, and beliefs, that permeates the whole European continent, and that is strongly expressed in the comparative uniformity of folk-tales.

For this reason European folk-lore creates the impression that the whole stories are units, that their cohesion is strong, and the whole complex very old. The analysis of American material, on the other hand, demonstrates that complex stories are new, that there is little cohesion between the component elements, and that the really old parts of tales are the incidents and a few simple plots.

Only a few stories form an exception to this rule—such as the Magic Flight or Obstacle myth—which are in themselves complex, the parts having no inner connection, and which have nevertheless a very wide distribution.

From a study of the distribution and composition of tales we must then infer that the imagination of the natives has played with a few plots, which were expanded by means of a number of motives that have a very wide distribution, and that there is comparatively little material that seems to belong to any one region exclusively, so that it might be considered as of autochthonous origin. The character of the folk-tales of each region lies rather in the selection of preponderant themes, in the style of plots, and in their literary development.

The supernatural element in tales shows a peculiar degree of variability. In a study of the varying details it appears a number of times that stories which in one region contain fantastic elements are given a much more matter-of-fact setting in others. I take my examples again from the north Pacific coast. In the tale of Raven's battle with South Wind we find in most cases an incident of an animal flying into the enemy's stomach, starting a fire, and thus compelling him to cough. In the Tsimshian version he simply starts a smudge in his house. In most tales of the liberation of the Sun the magical birth of Raven plays an important part, but among the Eskimo he invades the house by force or by ordinary fraud. In the Tsimshian tale of the origin of Raven a dead woman's child flies up to the sky, while the Tlingit tell the same tale without any supernatural element attached to it. Another case of this kind is presented by the wedge test as recorded among the Lower Thompson Indians. In most versions of this tale a boy who is sent into the open crack of a tree and whom his enemy tries to kill by knocking out the spreading-sticks, escapes miraculously when the tree closes. In the more rationalistic form of the tale he finds a hollow which he keeps open by means of supports given me. The available material gives me the impression that the loss of supernatural elements occurs, on the whole, near the border of the area in which the tales are known, so that it might be a concomitant of the fragmentary character of the tales. That loss of supernatural elements occurs under these conditions, appears clearly from the character of the Masset and Tlingit tales recorded by Swanton. In some of the Tlingit tales the supernatural elements are omitted, or weakened by saying that the person who had an incredible experience was out of his head. In the Masset series there are many cases in which the supernatural element is simply omitted. I am not prepared to say in how far this tendency may be due to conflicts between the tales and Christian teaching or in how far it may be due simply to the break with the past. The fact remains that the stories lost part of their supernatural character when they were told in a new environment.

I think it would be wrong to generalize and to assume that such loss of supernatural elements is throughout the fate of tales, for the distribution of explanatory tales shows very clearly that it is counterbalanced by another tendency of tales to take on new supernatural significance.

An additional word on the general theory of mythology. I presume I shall be accused of an entire lack of imagination and of failure to realize the poetic power of the primitive mind if I insist that the attempt to interpret mythology as a direct reflex of the contemplation of nature is not sustained by the facts.

Students of mythology have been accustomed to inquire into the

origin of myths without much regard to the modern history of myths. Still we have no reason to believe that the myth-forming processes of the last ten thousand years have differed materially from modern myth-making processes. The artifacts of man that date back to the end of the glacial period are so entirely of the same character as those left by the modern races, that I do not see any reason why we should suppose any change of mentality during this period. Neither is there any reason that would countenance the belief that during any part of this period intertribal contact has been materially different from what it is now. It seems reasonable to my mind, therefore, to base our opinions on the origin of mythology on a study of the growth of mythology as it occurs under our own eyes.

The facts that are brought out most clearly from a careful analysis of myths and folk-tales of an area like the northwest coast of America are that the contents of folk-tales and myths are largely the same, that the data show a continual flow of material from mythology to folk-tale and *vice versa,* and that neither group can claim priority. We furthermore observe that contents and form of mythology and folk-tales are determined by the conditions that determined early literary art.

The formulas of myths and folk-tales, if we disregard the particular incidents that form the substance with which the framework is filled in, are almost exclusively events that reflect the occurrences of human life, particularly those that stir the emotions of the people. If we once recognize that mythology has no claim to priority over novelistic folk-lore, then there is no reason why we should not be satisfied to explain the origin of these tales as due to the play of imagination with the events of human life.

It is somewhat different with the incidents of tales and myths, with the substance that gives to the tales and myths their highly imaginative character. It is true enough that these are not directly taken from every-day experience; that they are rather contradictory to it. Revival of the dead, disappearance of wounds, magical treasures, and plentiful food obtained without labor, are not every-day occurrences, but they are every-day wishes; and is it not one of the main characteristics of the imagination that it gives reality to wishes? Others are exaggerations of our experiences; as the power of speech given to animals, the enormous size of giants, or the diminutive stature of dwarfs. Or they are the materialization of the objects of fear; as the imaginative difficulties and dangers of war and the hunt, or the monsters besetting the steps of the unwary traveler. Still other elements of folk-lore represent ideas contrary to daily experiences; such as the numerous stories that deal with the absence of certain features of daily life, as fire, water, etc., or those in which birth or death are brought about by unusual means. Practically all

the supernatural occurrences of mythology may be interpreted by these exaggerations of imagination.

So far as our knowledge of mythology and folk-lore of modern people goes, we are justified in the opinion that the power of imagination of man is rather limited, that people much rather operate with the old stock of imaginative happenings than invent new ones.

There is only one point, and a fundamental one, that is not fully covered by the characteristic activity of imagination. It is the fact that everywhere tales attach themselves to phenomena of nature; that they become sometimes animal tales, sometimes tales dealing with the heavenly bodies. The distribution of these tales demonstrates clearly that the more thought is bestowed upon them by individuals deeply interested in these matters—by chiefs, priests, or poets—the more complex do they become, and the more definite are the local characteristics that they develop. The facts, however, do not show that the elements of which these tales are composed have any immediate connection with the phenomena of nature, for most of them retain the imaginative character just described.

The problem of mythology must therefore rather be looked for in the tendency of the mind to associate single tales with phenomena of nature and to give them an interpretative meaning. I do not doubt that when the anthropomorphization of sun and moon, of mountains and animals, had attracted stories of various kinds to them, then the moment set in when the observation of these bodies and of the animals still further stimulated the imagination and led to new forms of tales, that are the expressions of the contemplation of nature. I am, however, not prepared to admit that the present condition of myths indicates that these form any important part of primitive mythology.

That European myths happen to have developed in this direction—presumably by long-continued reinterpretation and systematization at the hands of poets and priests—does not prove that we must look for a poetic interpretation of nature as the primary background of all mythologies.

The mythological material collected in recent years, if examined in its relation to folk-tales and in its probable historical development, shows nothing that would necessitate the assumption that it originated from the contemplation of natural phenomena. It rather emphasizes the fact that its origin must be looked for in the imaginative tales dealing with the social life of the people.

Thomas Jefferson.

THOMAS JEFFERSON IN RELATION TO BOTANY

BY RODNEY H. TRUE

WE are all familiar with Thomas Jefferson, the writer of the Declaration of Independence and the first great American radical leader, but we are less familiar with the fact that amid the political tempests which raged around him he never ceased to live the life of an ardent lover of the world of living things. In the volumes of his correspondence there appear not only letters dealing with the momentous questions of national life, neutrality, peace or war, slavery or no slavery, government by the people or only government for the people, but also many to men of science dealing with the various questions that agitated their world a hundred years ago. Systems of classification, identity of doubtful plants, problems of the cultivator in field and green-house, the introduction of new and useful kinds, and the best apportionment of time to be given to the several sciences found in the college curriculum are among the subjects of consideration both with American and with European correspondents. Jefferson was interested in all *useful* branches of science, and since his conception of utility was very broad, few lines of research that had developed in his day failed to receive some attention from this tireless man. The name of our great scientist-statesman, Benjamin Franklin, will occur to all minds in this connection. Undoubtedly Franklin's work on electricity was one of the greatest achievements yet credited to America. It is doubtful, however, whether he was in touch with so wide a range of scientific interests as was Jefferson.

Before we undertake a more detailed consideration of Jefferson's relations to botany, let us try to put him in his botanical setting by recalling some of the chief landmarks set up in that science during the years of his long life. Born in 1743, Jefferson as a four-year-old boy might have known Dillenius at the time of his death. He was six years old when Mark Catesby, the author of the famous "History of Carolina, etc.," passed away. He was two years old when Gronovius published Clayton's "Flora of Virginia." The chief botanical figures of the period covered by Jefferson's youth were Jussieu, the eldest; Philip Miller, of the "Gardener's Dictionary"; Peter Collinson, the witty English Quaker botanist and correspondent of Linnæus; John Bartram, of Philadelphia, likewise a Quaker; Dr. Alexander Garden, of Charleston, and the great Linnæus himself. That this youth knew nothing at this time of these men is most probable. Although destined in a few

short years to write the immortal Declaration, then revolutionary doctrine, that nations and peoples have a right to freedom of development, he was now oblivious of the fact that Linnæus was engrossing the attention of the world of science by inaugurating his peaceful revolution in classification and nomenclature. He was much more concerned with the smiles and frowns of Miss Sukey Potter and her friend, Miss Belinda Burwell. As he entered young manhood, among the prominent figures of earlier days now passing from the stage were some familiar to us: Cadwallader Colden, the botanizing governor of the New York colony died in the year of the Declaration of Independence, Bernard de Jussieu and John Bartram one year later, Linnæus two years later, and his pupil, the Swedish botanical explorer, Peter Kalm, three years later.

Among those who were boys with Jefferson were Humphrey Marshall, one of that famous group of Philadelphia Quaker naturalists who left his mark on American botany in his little book entitled "Arbustum Americanum"; Adam Kuhn, the first professor of botany in the College of Philadelphia, and perhaps in the whole country; André Michaux, the elder of that pair of French travelers and naturalists who added so largely to the botanical knowledge of America, and lastly, Laurent de Jussieu, through whose work chiefly the so-called Natural System of Classification found form and currency.

In Jefferson's first administration (1801–1805), Dr. Benjamin S. Barton, of Philadelphia, published his "Elements of Botany," the first great American botanical text-book, and Dr. David Hosack established near New York his Elgin botanical garden, later attached to Columbia College.

In the years immediately following Jefferson's retirement from the presidency appeared Barton's "Flora Virginica" (in part), F. A. Michaux's "History of the Forest Trees of North America," Pursh's "Flora Americæ Septentrionalis," and Mühlenberg's "Catalogue," which a few years later was brought on to the basis of the Natural System by the versatile diplomat, Abbé Corrêa, the Portuguese Minister to the United States. This same period witnessed the remarkable advance in chemistry marked by the discovery of oxygen by Priestly, from whom Jefferson received many letters. The work of Ingenhauss, of Vienna, and that of DeSaussure and of Senebier at Geneva developed the basal facts concerning the gaseous interchanges taking place in respiration and photosynthesis in plants. Thomas A. Knight, the pioneer in physiology and plant breeding, and Sir Humphry Davy, the great chemist and physicist, lived their most active days concurrently with Jefferson—also that "scourge of the human race," Napoleon. Jefferson's death took place in 1826, the year of the appearance of Darlington's "Florula Cestrica." It will bring Jefferson nearer to us to recall that in that year Asa Gray, whom the older of us here present this evening might

have known and studied with, was already a boy of sixteen, while his distinguished associate, Dr. John Torrey, was a young man of thirty years.

Having now established Jefferson's location in botanical chronology, let us turn to the man himself and, during the time remaining to us, examine his relations to our science and its progress during his time. It seems clear, from the evidence at hand, that, interested as he was in all lines of progress, Jefferson felt himself especially attracted to botany. Indeed, he may have come by such a leaning honestly enough through his mother, Jane Randolph. She was the daughter of Isham Randolph of Goochland county, Virginia, whose interest in plants was known in his lifetime beyond the bounds of the American colonies.

Peter Collinson, the English Quaker botanist, commemorated by Linnæus in the generic name, *Collinsonia,* wrote in February, 1739, to his friend, John Bartram, the Quaker botanist of Philadelphia, who was about to undertake a tour of scientific investigation into Virginia:

> Then when thee proceeds home, I know no person who will make thee more welcome than Isham Randolph. He lives thirty or forty miles above the falls of the James River, in Goochland—above the other settlements. Now I take his house to be a very suitable place to make a settlement at—for to take several days' excursions all around, and to return to his house at night.

His further advice to Friend Bartram is hardly botanical in its subject matter, but since it sheds light on Jefferson's grandfather and on his way of living in that remote frontier settlement, I may perhaps be permitted to quote a few lines further.

> One thing I must desire of thee, and do insist that thee oblige me therein; that thou make up that drugget clothes, to go to Virginia in, and not appear to disgrace thyself or me; for though I should not esteem thee the less, to come to me in what dress thou will,—yet these Virginians are a very gentle, well-dressed people—and look, perhaps, more at a man's outside than his inside. For these and other reasons, pray go very clean, neat, and handsomely dressed to Virginia. Never mind thy clothes, I will send more another year.''

He met Isham and found him all that Collinson had promised. Moreover, Bartram found Isham able to guide him to an interesting conifer which Bartram later pronounced "much the finest Arborvitæ, surpassing one he had obtained from Cadwallader Colden from Hudson's River."

However it came about, by inheritance or otherwise, we may be assured that Jefferson's interest in botany was unusually keen. Writing in November, 1808, to his son-in-law, Colonel Thomas Mann Randolph, concerning the education of his grandson, Thomas Jefferson, then President at Washington, says:

> For a scientific man in town nothing can furnish so convenient an amusement as chemistry, because it can be pursued in his cabinet; but for a country gentleman, I know no source of amusement and health equal to botany and

natural history; and I should think it unfortunate for such an one to attach himself to chemistry, altho' the general principles of the science it is certainly well to understand.

In a letter written October 7, 1814, to Dr. Thomas Cooper of Columbia, S. C., in which university courses are the subject of discussion, Jefferson claims for botany a high rank among the practical sciences, since it deals with the sources of food, fibers and other important products, among which he mentions ornamentals. Botany as a humanizing influence again finds its office recognized.

No country gentleman should be without what amuses every step he takes into his fields.

The interest taken by Jefferson in the study of plants seems to have been shared by several of his plantation-owning neighbors. Indeed, the circumstances surrounding the Virginia planter before the coming to life of the slavery issue were probably as favorable to the development of the accomplishments and graces as have ever existed. Large interests close at hand, supervised by his own eye, an abundant living and few distractions beyond those incident to the hospitalities of the times gave the possessor the leisure needed for the cultivation of such interests as might commend themselves to him. It is then hardly surprising that in a region shown by Bartram and others to be so rich in new and interesting plants there should be a marked activity in the study of botany among the men of leisure living there.

It is probable that Jefferson's early interest in the subject may have been such an amateur interest intensified by his inheritance of some of the tendencies seen in Isham Randolph. It seems to have been characteristic of Jefferson that when his interest in a subject was really aroused he went into the matter as far as circumstances would permit. In his desire to have the necessary resources at hand, the available book markets were ransacked. Like the true collector, he was not satisfied to borrow a book, he must needs own it, then lend it generously to others and perhaps lose it. A single letter may suffice to illustrate one of these characteristics. It was written in January, 1783, at Philadelphia, where Jefferson was Washington's Secretary of State, to Mr. Francis Eppes, a neighboring planter and father of his future son-in-law. Mr. Eppes, acting as Jefferson's emissary, was trying to get a much-desired book from his neighbor, Mr. Bolling. After writing about Gibraltar and affairs at the British court Jefferson says:

Since I came here there has been sold the Westover copy of Catesby's History of Carolina. It was held near a twelve month at twelve guineas, and at last sold for ten. This seems to fix what should be given for Mr. Bolling's copy, if you can induce him to let you have it, which I am anxious for.

It is not known what success Mr. Eppes had with Mr. Bolling, but among the remarkable collection of books which Jefferson made and which in 1815 became the nucleus of the present Library of Congress,

there was a copy of Catesby. His botanical library became in time one of the best in America, a fact attested by the frequent loan of rare volumes to students of plants not so fortunate as to own copies themselves.

Remarkable as was the breadth and intensity of Jefferson's interests in affairs, he was not the author of many books. The service demanded of him by state and country with little intermission from his election to the House of Burgesses of the Colony of Virginia in 1769 to his retirement from the Presidency forty years later, gave him at no time the continuous leisure required for doing any large body of original investigation. We find, therefore, outside of the myriad references more or less extended to matters of science (and botany in particular) preserved in his very voluminous correspondence, but one extended work, a book appearing first under date of 1782, entitled "Notes on Virginia." And that book became one through no deliberate intention on the part of Jefferson to be an author on this subject. His friend, the French representative to America, M. de Marbois, wishing information for friends in Europe, begged Jefferson to set down answers to a series of questions dealing with the main points of interest and importance concerning his native state. In response to this request, Jefferson wrote down rapidly and without great research the series of chapters which eventually became the book mentioned. These chapters dealt more completely and scientifically with Virginia than any previous work had done with any of the sister states and has been referred to by General Greely as the first great American contribution to scientific geography. The book ran through many editions in English, and through several in a very inaccurate French version published without Jefferson's knowledge or consent. A German edition also appeared.

Probably this book represents the first important contribution made by Jefferson to biological science and serves as a landmark in his career. The chapter dealing with the flora of the state gives lists of medicinal, esculent, ornamental and otherwise useful native plants. The common names as well as the Linnæan names were used. Not finding the pecan described in Miller, Linnæus or Clayton, he says, "Were I to venture to describe this, speaking of the fruit from memory, and of the leaf from plants of two years' growth, I should specify Juglans alba, foliolis lanceolatis, acuminatis, serratis, tomentosis, fructa minore, ovato, compresso, vix insculpto, dulci, putamine tenerrime," (which translated says this: Juglans alba, with leaflets lanceolate, acuminate, serrate, tomentose, fruit small, ovate, compressed, little sculptured, sweet, shell thin.) "It grows on the Illinois, Wabash, Ohio and Mississippi." This description was written in 1781 or early in 1782 and appeared in print in Paris in 1784, one year before Humphrey Marshall described the pecan in his "Arbustum Americanum," the work in which the

nomenclatorial history of this tree is considered by some to have had its beginning.

In order to contrast the botanical workmanship of Jefferson with that of Marshall, I will read the description in the "Arbustum Americanum" p. 69, on which Marshall has received credit for first introducing the pecan to science:

> 8. *Juglans* pecan. The Pecan or Illinois Hickery.
>
> This tree is said to grow plenty in the neighborhood of the Illinois River, and other parts to the Westward. The young trees raised from these nuts, much resemble our young Pig-nut Hickeries. The nuts are small and thin shelled.

To my mind Marshall's description fails to distinguish the pecan plant from the pig-nut hickory he mentions, while the name proposed by him is left so nearly nude that its title to priority is doubtful. The earlier, clean-cut, adequate diagnosis by Jefferson, can only on bibliographic technicality fail to secure for him the credit of being the first scientific sponsor for the pecan.

As a matter of fact, the pecan had been known to several American botanists almost twenty-five years before either of these books appeared. Colonel Bouquet obtained them at Pittsburgh and gave them to John Bartram, who seems to have sent them to several of his correspondents. Peter Collinson and John St. Clair almost certainly received some in 1760 or 1761. Since at that time Jefferson was still at the Belinda Burwell-Sukey Potter stage, he could hardly have been interested in the interchange of letters between John Bartram and Peter Collinson produced by Colonel Bouquet's "seven hard, stony seeds shaped something like an acorn." It seems probable that Collinson showed these puzzling nuts to his friend, James Gordon, a prominent nurseryman living near London, whom the generic name of the Loblolly bay, *Gordonia,* commemorates. The result amuses Peter, who writes to his friend John:

> I do laugh at Gordon, for he guesses them to be a species of Hickory.

Then he continues, this time in the vein of true prophesy.

> Perhaps I may be laughed at in turn, for I think they may be what I wish, seeds of the Bonduc tree, (Kentucky coffee tree), which thou picked up in thy rambles on the Ohio.

Characteristically enough, Jefferson throughout his correspondence which turned not rarely on this nut, consistently refers to it as the paccan or Illinois nut. In France where he represented the United States in a diplomatic capacity, we find him enthusiastically introducing it to the Frenchmen. Writing from Paris on January 3, 1786, to his Philadelphia friend, Francis Hopkinson, the early American song writer and signer of the Declaration of Independence, after indicating a number of errands to be done for him, Jefferson says,

> The third commission is more distant. It is to procure me two or three hundred paccan-nuts from the Western country. I expect they can always be

got at Pittsburg, and am in hopes, that by yourself or your friends, some attentive person there may be engaged to send them to you.

He continues with characteristic explicitness:

They should come as fresh as possible, and come best, I believe, in a box of sand.

Nearly a year elapses before he hears from Hopkinson who evidently is not clear that he has obtained the right thing and Jefferson replies to him from Paris, December 23, 1786. "The paccan nut is, as you conjecture, the Illinois nut. The former is the vulgar name south of the Potomac, as also with the Indians and Spaniards, and enters also into the botanical name, which is *Juglans paccan*." Here it will be noted he adopts Marshall's proposed name.

During the years spent in Paris, Jefferson was at the very heart of European activity and in the lack of newspapers he served as a reporter on the progress of science for some of his American friends as well as for Harvard, Yale, and perhaps other institutions. Among those to whom he frequently wrote on subjects of this nature was his good friend Bishop James Madison, the President of William and Mary College, at Williamsburg, Va. A letter written by him on July 19, 1788, at Paris will show how well Jefferson played the part of scientific scout for America.

You know also that Dr. Ingenhauss had discovered, as he supposed, from experiment, that vegetation might be promoted by occasioning streams of the electrical fluid to pass through a plant, and that other physicians had received and confirmed this theory. He now, however, retracts it, and finds by more decisive experiments, that the electrical fluid can neither retard nor forward vegetation. Uncorrected still of the rage of drawing general conclusions from partial and equivocal observations, he hazards the opinion that *light* promotes vegetation. I have heretofore supposed from observation, that light affects the color of living bodies, whether vegetable or animal; but that either the one or the other receives nutriment from that fluid must be permitted to be doubted of, till better confirmed by observation.

The state of physics at that time is keenly illuminated by his remarks on light as a fluid like electricity. How inadequate the view before the conceptions of energetics entered is shown by the remark concerning the non-nutritiousness of the light fluid.

Jefferson closes this letter with a little rather debatable philosophy growing out of this ill fortune of the efforts of Ingenhauss.

It is always better to have no ideas than false ones; to believe nothing, than to believe what is wrong. In my mind, theories are more easily demolished than rebuilt.

Fortunately for Thomas Jefferson and for us, he was never able to rigidly follow this creed of skepticism. Of the truth of his observation on the perishability of theories we can all bear him witness.

It may be of interest to note in passing that last year I found among the remains of Jefferson's library now in the Library of Congress a copy of Ingenhauss's book entitled "Experiments on Vegetables."

In 1791 in company with his plant-loving friend Madison, Jefferson

had occasion to take an extended turn through the Northern States. This opened to their eyes a new flora as seen in the first week of June. Jefferson writes enthusiastically to his son-in-law, and fellow lover of plants, Thomas Mann Randolph:

BENNINGTON IN VERMONT, June 5, 1791.

Dear Sir: Mr. Madison and myself are so far on the tour we had projected.

After describing the battlefield of Saratoga he continues:

We have also visited Forts William, Henry and George, Ticonderoga, Crown Point, etc., which have been scenes of blood from a very early part of history—We were more pleased, however, with the botanical objects which continually presented themselves. Those either unknown or rare in Virginia, were the sugar maple in vast abundance, the silver fir, white pine, pitch pine, spruce pine, a shrub with decumbent stems, which they call juniper, an azalea very different from the nudiflora, with very large clusters of flowers, more thickly set on the branches, of a deeper red and high pink-fragrance. It is the richest shrub I have seen. The honeysuckle of the gardens growing wild on the banks of Lake George, the paper birch, an aspen with a velvet leaf, a shrub-willow with downy catkins, a wild gooseberry, a wild cherry with single fruit (not the bunch cherry), strawberries in abundance.

The azalea here referred to with such enthusiasm, was in the opinion of Mr. W. W. Eggleston, probably *A. canescens,* first normally described twelve years later in 1803 by Michaux the elder. Had Jefferson taken the trouble to give his observations the form of conventional descriptions, it is quite likely that his discoveries would have added several plants then new to science.

During the next decade, that preceding his first presidency, Jefferson found his time very largely occupied with the duties involved in the positions of Secretary of State, under Washington, and Vice-president with John Adams, but incidentally he serves as President of the American Philosophical Society, he writes an essay on the study of Anglo-Saxon, he drafts the famous Kentucky resolutions, makes preliminary plans for an educational institution which in the later years of his life became the University of Virginia, and prepares a parliamentary manual, still in very general use in legislative assembles. During this period he was the recognized leader of the newly formed Republican party and as such was involved in what was perhaps the most bitter partisan contest ever waged in our political history.

During this period there are many incidental proofs of his continued pleasure in botany as when on April 1, 1892, at Mrs. Trist's desire he sends to Benjamin Hawkins

about a dozen beans of three different kinds, having first taken toll of them as she has done before. They are of the scarlet flowering kind. This is all I know of them. The most beautiful bean in the world is the Caracalla bean, which though in England a greenhouse plant, will grow in the open air in Virginia and Carolina. I could never get one of these in my life. They are worthy your enquiry.

On June 2, 1793, writing from Philadelphia, he does a good turn for his friend John by writing to James Madison:

Bartram is exceedingly anxious to get a large supply of seeds of the Kentucky coffee tree. I told him I would use all my interest with you to obtain it, as I think I heard you say some neighbors of yours had a large number of trees. Be so good as to take measures for bringing a good quantity, if possible, to Bartram when you come to Congress.

During his stay in Paris from 1784 to 1789, Jefferson had made the acquaintance of many men of science, and his reputation brought him many correspondence-acquaintances. When, therefore, the French Revolution, later became European chaos through the deeds of Napoleon, many men of science found little opportunity to pursue their studies. Jefferson received letters from several of these friends who desired a quiet haven in America. The University of Geneva, with Edinburgh, declared by Jefferson to be the "eyes of Europe" was involved in the general disaster. Washington, having received a present from Virginia in the shape of some shares in the Potomac and James River Companies, desired to place them where in some far-reaching way they might work for the public good, and before bestowing them sought Jefferson's advice. With a boldness which was characteristic of him when great opportunities were in sight, Jefferson proposed to Washington the transfer bodily of the University of Geneva to some place near the Federal city (Washington) where it should become the beginning of the National University of America. He proposed the organization of a professorship in agriculture which should present this branch in a series of lectures. The University was not transferred and Jefferson's glorious dream faded. One can not but ponder what such a transfer would have meant to America. The germ of the most important work in plant physiology lay in two members of that faculty. Through the epoch-making work of Theodor de Saussure and of Jean Senebier, aided by their above condemned Austrian colleague Ingenhauss, the foundations for the understanding of the processes of photosynthesis and respiration were laid. At the time this bold conception captured Jefferson these men were approaching their prime, only a few years later to dazzle the world of science with their brilliant achievements. Had that work been performed at the new National University of America situated near the Federal city one of the great ideals of Jefferson's life would have been realized.

The relation of Jefferson to science and botany in particular up to the time of his first presidency had been essentially that of a keenly interested and very intelligent amateur. He had been an intermediary between scientists, had on several occasions expressed his own views on current scientific problems and in some cases had anticipated the specialists themselves.

In 1802, however, the greatest scientific opportunity of his life came to Jefferson with the purchase of Louisiana. At this time there came under the flag of the United States a vast unknown area for exploration and settlement. The Missouri River with St. Louis as a starting point had for years been a highway into that country swarming with

herds of bison and antelope and peopled with war-like but interesting Indian tribes. Fur traders and their like had brought back such information as was to be had about the country. The fascination of this great unknown wilderness had long before taken possession of Jefferson. While a resident in Paris he had become acquainted with John Ledyard, one of those nomads who roamed the world in search of adventure. Ledyard had been with Captain Cook in his famous voyage through Behring Straits and was with him on his last fateful visit to the Sandwich Islands. He came to Paris in 1786 ready for a new quest and was urged by Jefferson to traverse Europe and Siberia to Kamschatka, to cross in Russian vessels to Alaska, then a Russian possession, to go southward to the latitude of the Missouri River, from which point he was to travel eastward to the headwaters of that river and along its course through Louisiana to the United States. Ledyard attempted to carry out this program, but through interference from the Russian government his plans were thwarted.

Nothing daunted by the unhappy outcome of this attempt, Jefferson proposed to the American Philosophical Society that a subscription be made up from private sources to finance an expedition up the Missouri River from St. Louis to cross what Jefferson called the "stony mountains"[1] to some corresponding stream on their farther slope, the course of which was to be traced westward to the ocean. Caspar Wistar, getting wind of these plans, in June, 1792, tried to get his Philadelphia friend Dr. Moses Marshall to confer with Jefferson with the purpose in view of undertaking the task.[2] But Dr. Marshall having been appointed justice of the peace, was diverted permanently from botany (Harshberger). The leadership was proposed to André Michaux, who accepted the rather rigorous terms of the promoters of the enterprise. Jefferson, speaking for the Philosophical Society, gave Michaux his instructions which, did time permit, would make very interesting reading. Michaux reached Kentucky only to be recalled by the French government to carry out a program of exploration for which he had been previously employed by it.

A third attempt was soon planned, this time with government aid. In January, 1803, acting on a confidential message from Jefferson, Congress approved his recommendation that a sum deemed sufficient to carry out the project be appropriated, and Jefferson lost no time in appointing his old neighbor and private secretary, Captain Meriwether Lewis, to take charge of the expedition. After associating with himself William Clark of Kentucky, Lewis, in April, 1803, received the necessary credentials and instructions from President Jefferson covering all points of policy likely to arise. To prepare himself the better for his work Lewis spent some months in Philadelphia receiving instruction

[1] Mem. Ed., XVIII, 144.

[2] Darlington, "Memorials of John Bartram and Humphrey Marshall," p. 570.

in science from the eminent men residing there. Dr. Benjamin S. Barton chiefly took his tuition in botany in hand and consulted freely on those phases of the plan dealing with zoology and anthropology as well. The expedition, despite much fatigue and suffering, was carried out successfully and after about two years' absence returned with much material of great value to natural history. In accordance with the terms of the agreement with the government, Captain Lewis was to have charge of the working up of the material and was to retain the right to first publish the results. The collections seem to have been placed by Lewis in the hands of qualified investigators before he assumed the post as governor of the new Louisiana territory to which he was soon appointed. Not long after, while suffering from a mental illness, he is said to have committed suicide. The decease soon after of Dr. Benjamin S. Barton, who was in charge of much of the material, and the bankruptcy of the bookmaker who was to have published the results threatened even at this late date to frustrate the object of the entire undertaking. The story of the adventures of the herbarium material makes a tale to stir botanists. We shall get a part of it from letters quoted below.

The seeds collected by the expedition seem in a measure to have been taken in charge by Jefferson, who divided the major part of them into two portions, which were given to Bernard McMahon, a botanist and nurseryman living in Philadelphia and to William Hamilton of the same place, the wealthy owner of the famous gardens known as "The Woodlands," by whom they were successfully grown.

The history of a number of the plants grown from these seed is traced in the correspondence between Jefferson and McMahon. These letters show, moreover, that Jefferson was the one stable element in the chaotic situation that had come to pass, and in the end he more than any other one man was able to save and bring within reach of the public the results of this expedition. McMahon writes from

PHILADELPHIA, June 28, 1808.

Dear Sir: I am happy to inform you that I have fine plants of all the varieties of currants (7) and gooseberries (2) brought by Govr. Lewis, and of about 20 other new species of plants, as well as five or six new genera; This will add to natural history and the plants are forthcoming.

To this Jefferson replies (in part), from

WASHINGTON, July 6, 08.

. . . I received only a few of Govr. Lewis's articles and have here growing only his salsafia, mandane corn and a pea remarkable for its beautiful blossom and leaf, his forward bean is growing in my neighborhood.

On December 24, 1809, not long after the tragic death of Governor Lewis became known, McMahon writes from Philadelphia:

I am extremely sorry for the death of that worthy and valuable man, Govr. Lewis, and the more so, for the manner of it. I have, I believe, all his collection of dried specimens of plants, procured during his journey to the

Pacific Ocean, and several kinds of new living plants, which I raised from the seed of his collecting which you and himself were pleased to give me. In consequence of a hint to that effect, given me by Govr. Lewis on his leaving this City, I never yet parted with one of the plants raised from his seeds, nor with a single seed the produce of either of them, for fear they would make their way into the hands of any botanist, either in America or Europe who might rob Mr. Lewis of the right he had to first describe and name his discoveries, in his intended publication; and indeed, I had strong reasons to believe this opportunity was coveted by ——— ——— which made me still more careful of the plants.

On Governor Lewis's departure from here, for the seat of his government, he requested me to employ Mr. Frederick Pursh, on his return from a collecting excursion he was then about to undertake for Dr. Barton, to describe and make drawings of such of his collection as would appear to be new plants and that himself would return to Philadelphia in the month of May following. About the first of the ensuing November, Mr. Pursh returned, took up his abode with me, began the work, progressed as far as he could without further explanation in some cases, from Mr. Lewis, and was detained by me, on expectation of Mr. Lewis's arrival at my expense, without the least expectation of any future remuneration, from that time till April last; when not having received any reply to several letters I had written from time to time, to Govr. Lewis on the subject, not being able to obtain any information when he might be expected here, I thought it a folly to keep Pursh longer idle, and recommended him as gardener to Dr. Hosack of New York, with whom he has since lived. The original specimens are all in my hands, but Mr. Pursh had taken his drawings and descriptions with him, and will, no doubt, on the delivery of them expect a reasonable compensation for his trouble. As it appears to me probable that you will interest yourself in having the discoveries of Mr. Lewis published, I think it a duty incumbent on me to give you (*the Ms. is here torn*) preceding information, and to ask your advice as to the propriety of still keeping the living plants I have from getting into other hands who would gladly describe and publish them without doing due honor to the memory and merit of the worthy discoverer. I am, sir, with the most sincere esteem, your well wisher, etc.

BERND. MCMAHON

It is not necessary to philosophize on the sad state of those times when botanists were jealous of each other's new species. The part played by McMahon, the gardener, seedsman and botanist, as a sort of central, connecting Lewis, the collector, Pursh, the botanist, and Jefferson, the prime mover in the whole enterprise is clearly indicated.

Not to tarry longer, it may be said that from the seeds placed with McMahon and Hamilton for propagation at the hands of expert gardeners came several plants well known to us all. The osage orange, or bois d'arc (*Maclura pomifera* Schneider) in time came into very general use in the central and southern parts of the country as a hedge plant. Others are mentioned in subsequent letters.

On February 18, 1812, McMahon sent to Jefferson among other of Lewis's plants, (1) "*Ribes odoratissimum* (Mihi), an important shrub, the fruit very large, of a dark purple colour, the flowers yellow, showy and *extremely fragrant*"; (2) *Symphoricarpos leucocarpa* (Mihi), which he described and to which he gives the English name of Snowberry bush, which it still retains; (3) "The yellow currant of the

River Jefferson, that is specifically different from the other, but I have not given it a specific botanical name." He closes his letter by referring to another subject which is quoted as showing his attitude toward Jefferson in a botanical matter.

I would thank you to inform me whether you take the Glocester nut to be a distinct species as announced by Michaux f. (*Juglans laciniosa*) or whether if only a variety it is nearer allied to the *Juglans tomentosa* Mich. or to the *J. squamosa* Mich. fi, the *J. alba* of his father.

But I must not quote more of this interesting correspondence.

In time, through the help of Abbé Corrêa de Serra and others, Jefferson was able to rescue a considerable part of the notes of the Lewis and Clark expedition from their various hiding places and to get them into the hands of a publisher, Paul Allen, for whom he wrote a brief biographical sketch of Meriwether Lewis.

Speaking summarily of Jefferson's relation to the Lewis and Clark expedition, it is clear that Jefferson inspired and sustained this famous enterprise, determined its course and in the end, outliving all others who had had a scientific interest in the enterprise, secured the benefits of its results to the country. Viewed broadly, this expedition was perhaps Jefferson's greatest contribution to science in general and to botany in particular.

During the years of retirement at Monticello, he took an interest in whatever was happening in the world of ideas. His correspondence with botanists at that period touches on all phases of the science then developing. The old artificial system of classification proposed by Linnæus had proved a great blessing when it was formulated, but as the study of life became more thorough and comprehensive, it is not surprising that new standpoints should have developed and that some system of arrangement should have been sought that in a certain ideal way would express more fully the truths of affinity and relationship than did the Linnæan system. Hence, it came about that the so-called "Natural System" associated with the name of Laurent de Jussieu formulated in his "Genera Plantarum" attracted much attention in the scientific world in 1789. In those days ideas were propagated rather slowly from their point of origin and it was not till nearly twenty-five years later that the reign of the Linnæan system was challenged in America. In 1815, the Abbé Corrêa de Serra, then lecturing on botany in the College of Philadelphia in succession to Benj. S. Barton, reduced Mühlenberg's "Catalogue" to the Natural System for the use of his hearers. Jefferson, in his retirement, was not entirely outside of the reach of ensuing botanical controversy. Since his opinion seems to have been solicited by numerous correspondents on many subjects of disagreement, we are not surprised to find Dr. John Manners subjecting the aged ex-president to a catechetical examination on the articles of his taxonomic faith. On January 24, 1814, Dr. Manners desires to know the comparative merits of the different methods of classifica-

tion adopted by different writers on Natural History. In his rather complete reply to the doctor written from Monticello, February 22, 1814, Jefferson approaches the problem in its broadest possible aspect. I quote here only in part.

> . . . The text of this answer will be found in an observation in your letter, when, speaking of the nosological systems, you say that disease has been found to be an unit. Nature, has, in truth, produced units only through all her works. Classes, orders, genera, species are not of her work. Her creation is of individuals. No two animals are exactly alike; no two plants, nor even two leaves or blades of grass; no two crystallizations. . . . This infinitude of units or individuals are far beyond the capacity of our memory. We are obliged, in aid of that, to distribute them into masses, throwing into each of these all individuals which have a certain degree of resemblance; to subdivide these again into smaller groups, according to certain points of dissimilitude observable in them, and so on until we have formed what we call a series of classes, orders, genera and species. In doing this we arbitrarily fix on such characteristic resemblances and differences as seem to us most prominent and invariable in the several subjects, and most likely to take a strong hold in our memories. Thus Ray formed one classification on such lines of division as struck him most favorable; Klein adopted another; Brisson a third, and other naturalists other designations, till Linnæus appeared. Fortunately for science, he conceived in the three kingdoms of nature, modes of classification which obtained the approbation of the learned of all nations. His system was accordingly adopted by all, and united all in a general language. . . . This classification was indeed liable to the imperfection of bringing into the same group individuals which, though resembling in the characteristics adopted by the author for his classification, yet have strong marks of dissimilitude in other respects. But to this objection every mode of classification must be liable. . . . Nature has not arranged her productions on a single and direct line. They branch at every step, and in every direction, and he who attempts to reduce them into departments, is left to do it by the lines of his own fancy. . . . But neither is this so important a consideration as that of uniting all nations under one language in Natural History. . . . Linnæus' method was received, understood and conventionally settled among the learned, and was even getting into common use. To disturb it then was unfortunate. The new system attempted in botany by Jussieu . . . is subject to the same regret. . . . I adhere to the Linnæan (system) because it is sufficient as a ground-work, admits of supplementary insertions as new productions are discovered, and mainly because it has got into so general use that it will not be easy to displace it, and still less to find another which shall have the same singular fortune of obtaining the general consent. . . . I am not myself apt to be alarmed at innovations recommended by reason. That dread belongs to those whose interests or prejudices shrink from the advance of truth and science. My reluctance is to give up an universal language of which we are in possession, without an insurance of general consent to receive another.

There would seem to be little encouragement here for a bibliographic botanist with his new combinations and resurrected ghost species; and as little for the man who regards a proposed new species as a piece of property belonging to him by moral right. The greatest service to the greatest number was the test to which Jefferson brought all things.

We must now pass to the consideration of another phase of Jefferson's influence on botany, that exerted in the academic sphere. And

we are not surprised to learn that largely as a result of Jefferson's initiative, the State of Virginia in 1818 appropriated the sum of $15,000 to be devoted to the building, equipment and manning of a State University. Likewise, largely through the influence of Jefferson, it came eventually to be located at Charlottesville. In spite of his many years, Jefferson was chosen head of the institution. In calling him to be rector of the university, the authorities could have hardly known how well they had chosen. Jefferson, already beyond his three score and ten, now turned architect and planned and caused to be built those structures which have made the University of Virginia one of the famous shrines of the building art in America. Then came the filling of eight professorships, chiefly by men from abroad. That of Natural History was filled on March 4, 1825, by the appointment of Dr. John Patten Emmett of New York, who was called to occupy, not a chair, but as somebody else has said, "a bench," for he gave instruction in chemistry, botany, zoology, mineralogy, and geology Being himself a chemist one is not surprised to find him in the following year pleading with the rector for a laboratory room for his chemistry work. It seems likely that he found it hard to get time for the botany since Jefferson seems to have been compelled to write him a letter asking him to plan on getting his botany courses into operation.

This letter shows the same energy, foresight, and sense for the practicable that put through the exploration of Louisiana. It is full of the enthusiasm for botany that he looked for in his young professor, but what is more to our present purpose, it gives a clear idea of what was taught under the name of botany in those days, and what equipment was regarded as necessary. On April 27, 1826, he wrote to Dr. Emmett as follows:

Dear Sir: It is time to think of the introduction of the School of Botany into our Institution. Not that I suppose the lectures can be begun in the present year, but that we may this year make the preparations necessary for commencing them the next, for that branch, I presume, can be taught advantageously only during the short season while Nature is in general bloom, say, only during a certain portion of the months of April and May, when suspending the other branches of your department, that of Botany may claim your exclusive attention. Of this, however, you are to be the judge, as well as of what I may now propose on the subject of preparation.

He then refers to suggestions made at his request by the late Abbé Corrêa regarding the most advisable way of utilizing a plot of 6 acres of ground available for a botanic garden. The lower flatter stretches were best used for the garden of plants, the terraced hill slopes for the arboretum. Owing to lack of funds a greenhouse was not to be considered. This area was to be enclosed and a gardener of sufficient skill was to be engaged He then continues:

Make out a list of the plants thought necessary and sufficient for botanical purposes, and of the trees we propose to introduce and take measures in time for procuring them. As to the seeds of plants, much may be obtained from the gardeners of our own country. I have, moreover, a special resource. For

three and twenty years of the past twenty-five, my good friend Thouin, Superintendent of the Garden of Plants at Paris, has regularly sent me a box of seeds, of such exotics as to us, as would suit our climate, and containing nothing indigenous to our country. These I regularly sent to the public and private gardens of the other states, having as yet no employment for them here. But during the last two years this envoi has been intermitted, I know not why. I will immediately write and request a recommencement of that kind office, on the ground that we can now employ them ourselves. They can be here in the early spring. The trees I should propose would be exotics of distinguished usefulness, and accommodated to our climate. Such as the Larch, Cedar of Libanus, cork-oak, the Marronier (Spanish Chestnut), Mahogany?, the catachu or Indian rubber tree of Napul (30°), Teak tree or Indian oak of Burman (23°) the various woods of Brazil, etc. The seed of the Larch can be obtained from a tree at Monticello, cones of the cedar of Libanus are in most of our seedshops, or may be had fresh from the trees in English gardens. The Marronier and cork-oak, I can obtain from France. There is a Marronier at Mount Vernon, but it is a seedling, and not therefore select. The others may be got through the means of our Ministers and Consuls in the countries where they grow, or from the seed shops of England where they may very possibly be found.

He closes his letter with a characteristic clause, "but let us at once enter on the operations."

On May 2, about eight weeks before his death, he being then 83 years old, Jefferson explains in a long letter to Professor Emmett, who finds his time overloaded, how he can reduce his difficulties by careful planning.

Suppose then you give 12 doz. lectures a year: say 2 doz. to botany and zoology, 2 doz. to mineralogy and geology, and 2 doz. to chemistry, or I should think that mineralogy, geology and chemistry might be advantageously blended in the same course, then your year would be formed into two grand divisions, 1/3 to botany and zoology and 2/3 to chemistry and its associates, mineralogy and geology. You will say that 2/3 of a year, or any better estimated partition of it, can give but an inadequate knowledge of the whole science of chemistry, but consider that we do not expect our schools to turn out their alumni already enthroned on the pinnacles of their respective sciences, but only so far advanced in each as to be able to pursue them by themselves and to become Newtons and Leplaces by energies and perseverences to be continued through life.

In his day Jefferson was the recipient of many distinguished honors conferred by societies and universities in America and Europe. Well did DeKay, the naturalist, refer to him in his late years as "the Great Patriarch of American Natural History." His own estimate of his life's work is reflected in the epitaph beneath which he desired to rest:

Here was buried Thomas Jefferson author of the Declaration of Independence, of the statute of Virginia for religious freedom and father of the University of Virginia.

For the use of the portrait of Jefferson which illustrates this paper the writer is indebted to Mrs. Edwin Kirk, of Washington, D. C., a descendant of Jefferson. The engraving was made from an oil painting by Gilbert Stuart and is traditionally regarded by members of this branch of the family as one of the best portraits of their great ancestor.

OUR NATIONAL PROSPERITY
DISTRIBUTION OF PROPERTY AND INCOME

By CHAS. A. GILCHRIST
BERKELEY, CAL.

IT will be generally conceded that in the economics of an individual, his material prosperity is in direct proportion to his material wealth. This clearly reflects the ordinary meaning of the word prosperity. In the case of a nation, our first thought would be that the average or per capita wealth would fairly represent the national prosperity, but a little reflection will show that this is not the case. We can conceive of a nation in which the entire population save one were the abject slaves of that one, producing wealth of an absurdly luxurious sort for his use and consumption, and retaining for themselves the barest pittances. Here the per capita wealth might be very high, although practically the whole of the population would be on the verge of starvation. Egypt, at the time her ancient kings were building their great monuments, gives us a picture of a nation that approached such a condition. Where such inequality in distribution exists, the average wealth is no indication of the prosperity of a people, which may be estimated only by an examination into the extent of the inequality in distribution. The prosperity of any given people can not be measured by its wealth, but rather by that prosperity among its individuals that predominates. We can not think that the excessive wealth of some in any way averages up or compensates for the poverty of the masses.

There are two aspects of wealth—the property aspect and the income aspect. In speaking of property we refer to the stock of wealth, whereas income is the rate at which wealth is being acquired, as so much per day or per year. The national wealth is the sum of the wealths of all individuals and the national income is the sum of all individual incomes.[1]

Income may be divided into two parts, one which is consumed and one which is saved. If the rate of consumption be subtracted from income, the difference is the rate of saving.

All income is acquired by individuals through two clearly defined and undisputed sources. These are the income from labor or services rendered; and the income from property owned. But while income is thus *acquired*, it is *produced* solely by the labor element, notwithstand-

[1] Property and income nominally held to the account of corporate bodies or governments must here be considered as distributed among such individuals as are the real owners.

ing the fact that property is a factor in wealth production. It is a factor and not a producer in the same sense that the wheels of an engine are a factor and not a producer of the energy developed, which is derived solely from the potential energy of the coal. Not only may labor produce without property, but it is the producer *of* property. In short, property does not produce, it is an opportunity to produce.

The proposition that all income is produced by labor will be disputed, for at once there comes to mind that portion of income that arises through an increase in land values and which at first sight can not be attributed to production by labor. But—taking land values as typical of all forms of so called wealth not directly attributable to labor—the following propositions, at least, are evident: (1) That value attaches to land solely because land ownership is the privilege, through rent, of regularly acquiring the products of labor. (2) That in a society which is economically static to the extent that land values are stationary, *all* income is the product of labor. (3) That in the long run and in the world at large *all* income is unconditionally the product of labor since history shows us that civilizations, and therefore land values, rise and fall in long period oscillations. (4) That in a country like the United States where land values are increasing, such increase is only a part of property income, the other part consisting of rent on land values and returns from other forms of capital, all of which is unquestionably the product of labor.

In the absence of property incomes, service or labor incomes could be equivalent to the wealth produced, but since property incomes absorb some of this wealth, the average of service incomes must be less than the average wealth that service produces. Neglecting for the time being that part of property income arising through increase in land values, it is evident that the dual source of income—service and property—can not apply to the national income as a whole, which must be equivalent to the national production. This is to say that the distinction between the two kinds of income is a socially internal one, some have the property income *because* others have it not. A man may receive more or less than he produces, according as other men receive less or more than they produce, but not so with the community as a whole which receives just what it produces.[2]

In all the figures compiled in this investigation land values are included, partly because present methods of accounting make it difficult to distinguish these from the products of labor, and partly because to raise the distinction would be to raise questions beyond the scope of our survey. But we may remember that in so far as any form of wealth

[2] Foreign relations are here neglected. But in 1914 the excess of our wealth sent abroad ($470,000,000) was only about 1½ per cent. of our total wealth production for the year. To that extent approximately we were paying foreign nations a property income with our labor.

is not a product of labor, it is merely a "capitalized value" of an income consisting of the products of labor.

That the present distribution of wealth in the United States is exceedingly unequal is yearly becoming more and more apparent to even less thoughtful people. The question of the injustice in the distribution of either property or income, or of a remedy for that injustice, is not here at stake. Our purpose is to present graphically the spectacle of inequality as it exists, and its relation to our national prosperity of which we are accustomed to boast. We will first examine the distribution of property and then the distribution of income, for these correspond to the two ways in which we may think of prosperity.

There being no recent figures in regard to the distribution of property, it is necessary to content ourselves with the distribution of 1890. Fig. 1 shows in a graphic manner the distribution of 1890, but transformed so that the total wealth and population correspond to 1913. Since concentration is increasing, we may bear in mind that inequalities in distribution shown by this diagram are less than the actual inequalities of to-day. The family instead of the individual is here taken as the unit. The presumption is that unmarried adults are considered as families of one each, so that with few exceptions the total wealth of the country is represented in the diagram. Each family averages about five persons, of which two are, on the average, "gainfully employed."

The horizontal base line of the figure must be imagined as divided into 19,200,000 equal parts, one for each family in the country. The families are arranged in the order of their wealth, the wealthiest at the right end and the poorest at the left end. If over each of these minute divisions we erect a vertical line the height of which represents the amount of wealth owned by that family, the tops of these vertical lines can be connected by a continuous curved line, as shown. Since these vertical lines are arranged in the order of their length, the curved line or locus will everywhere slope up from left to right, but, aside from this, it might have any form according to the manner in which the total wealth was distributed among the families.

The striking feature of such a diagram is the fact that its area represents the total amount of wealth, and any portion of its area enclosed between vertical lines represents the wealth owned by the portion of the population that these lines intercept on the base line. The lined area, then, is the total wealth of the country, and that the great bulk of this wealth lays with the first tenth of the population is evident at a glance. Imagine the figure as a great piece of land of just that shape and of uniform fertility and usefulness throughout. Then if we divide it up by 19,200,000 equi-spaced fences, parallel to the straight line at the right end, the narrow strips so formed would be distributed one to each family, and as shown by the figure the first 10 or 20 per cent. of

the population would get practically the whole thing, while the land going to the last half of the population is a negligible share. In this mental picture we are merely taking land as typical of wealth in general.

So unequal is the distribution and so attenuated the shape of the figure, it was not possible to show satisfactorily the upper right portion of it. This limb must be imagined as extending upward to such a height that a half of the whole area lies in the right-hand strip corresponding to 1 per cent. of the population. The curve would finally meet the extreme right hand line in an exceedingly sharp point whose height would represent the fortune of the richest man in the country. Taking this at a billion dollars, the figure would have to be ten thousand times higher to show it. The pertinence of this diagram is not so much in the numerical values that may be scaled from it, but in the graphic or pictorial impression we get from the manner in which the area is distributed with regard to the horizontal base line. However, *1 per cent. of the people own more than the remaining ninety-nine!* Think of it! One half the national wealth practically crossed out as

FIG. 1. This diagram is based upon an estimate for 1890 by Charles B. Spahr. (See his "The Present Distribution of Wealth," pp. 69.) The diagram shows the wealth and population of 1918 with the distribution of 1890. It was made by prorating from one period to the other by population and total wealth. Spahr's figures thus transformed give:

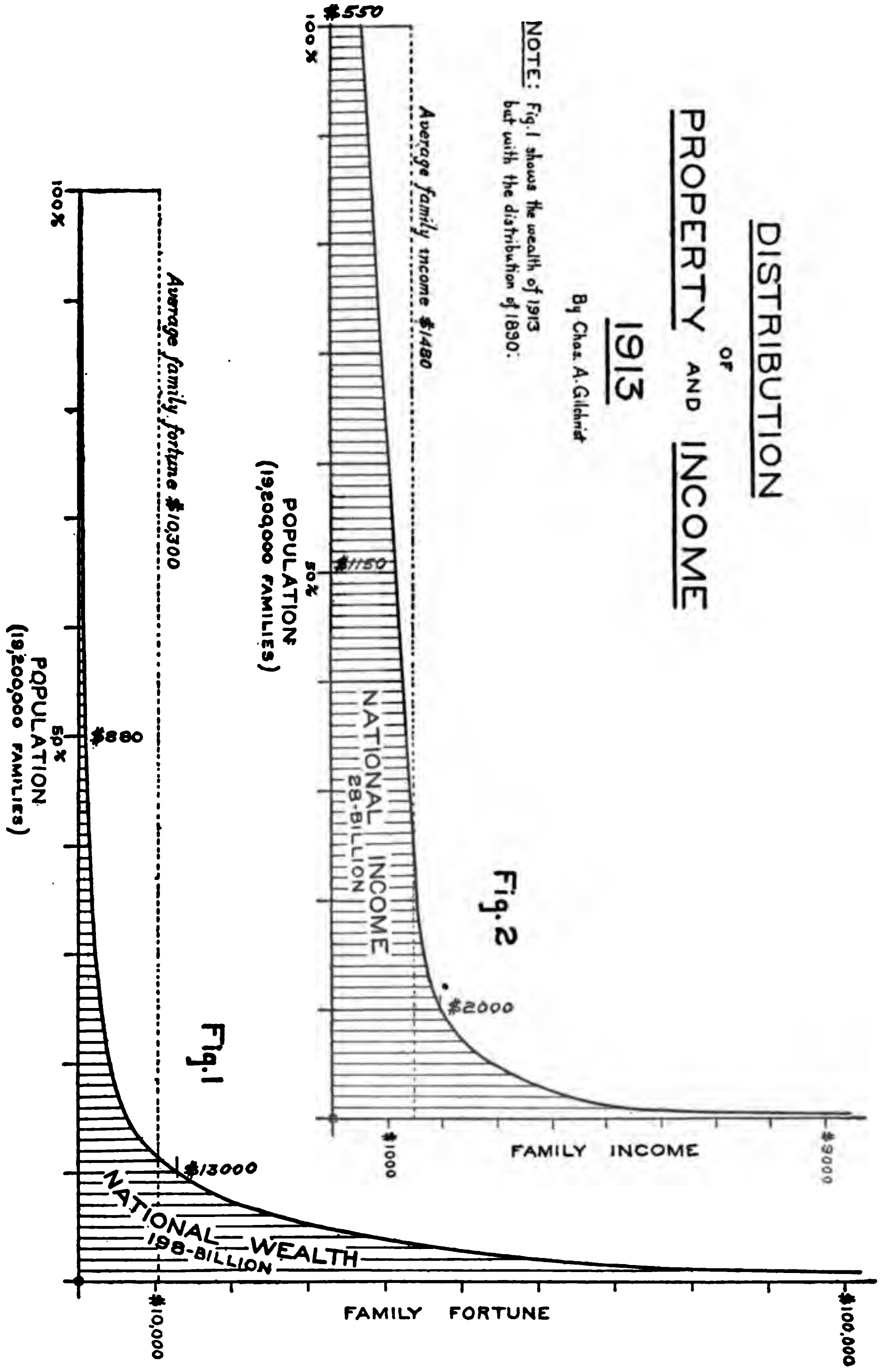
Families					Total for Group
88.5%	or	17,000,000	own	under $10,000	$27,450,000,000
10.5	or	2,000,000	own	$10,000 to $100,000	70,150,000,000
1.0	or	200,000	own	$100,000 and over	100,650,000,000
100%		19,200,000			$198,250,000,000

These data were sufficient to fix but two points on the curve, but the total wealth between these points being given, the intervening curve was drawn with just enough concavity to make the area below it equivalent to that amount of wealth. In the same way the amount of wealth for all those families owning less than $10,000 determined the concavity of the left end of the curve. If the wealth of every family was known and plotted, the resulting curve would undoubtedly be less smooth and continuous than the one drawn, but it would follow the general trend of that curve.

FIG. 2. Figures for this diagram were first compiled for what the census calls "persons gainfully employed," and then transformed to the family as a unit on the basis of 42 per cent. of population gainfully employed, and 5.05 persons to the family. This is equivalent to 2.1 persons gainfully employed, to the family.

Personal incomes below $1000 ($2100 family income) were apportioned by figures of Scott Nearing for the year 1913. (See his "Income," pp. 106.) Incomes above $2500 were taken from the Annual Report of the Commissioner of Internal Revenue for 1914, and increased 20 per cent. to cover omissions. (Income tax returns, pp. 112.) Incomes between $1000 and $2500 were allotted to the remaining population. Transformed to families, these figures give:

Families				Total Income of Group
42.6%	or	8,200,000	under $1050	$6,600,000,000
39.7	or	7,614,000	$1050 to 1575	10,100,000,000
9.0	or	1,720,000	1575 to 2100	3,100,000,000
7.8	or	1,500,000	2100 to 5250	4,900,000,000
.9	or	166,000	5250 and over	3,800,000,000
100%		19,200,000		$28,500,000,000


DISTRIBUTION
OF
PROPERTY AND INCOME
1913
By Chas. A. Gilchrist
NOTE: Fig. 1 shows the wealth of 1913 but with the distribution of 1890.
Fig. 2
Average family income $1480
$550
$1150
$2000
NATIONAL INCOME 28-BILLION
POPULATION (19,200,000 FAMILIES)
100%
50%
FAMILY INCOME
$1000
$9000
Fig. 1
Average family fortune $10,300
$880
$13000
NATIONAL WEALTH 198-BILLION
POPULATION (19,200,000 FAMILIES)
100%
50%
FAMILY FORTUNE
$10,000
$100,000

far as national prosperity goes, since it is the property of but 1 per cent. of the population! Four fifths of the people own but one tenth of the wealth!

The dotted line showing the average wealth per family is seen to be not the least indication of what families in general are worth, seeing that 70 per cent. of the families do not own even a fifth of the average family wealth. There is a big difference between the *average* family wealth and the *predominating* family wealth. The family midway between the extremes is worth about $880 and this is perhaps as near as any one figure may come to expressing the family wealth that predominates among such enormous variations. Would not the prosperity of the nation be far more truly reflected in this middle family wealth of $880, than in the average family wealth of $10,300? The one is the wealth of the average family and the other is the average wealth of families. The complete failure of the significance of the average is strikingly shown by the fact that the *mean variation* from the average is $15,500[3]—more than the average itself.

Turning now to examine the distribution of income, we find that it differs in a marked way from the distribution of property. Fig. 2, which is the diagram for income distribution, is constructed in precisely the same way that the diagram for property was constructed—areas represent total incomes.

Had we not examined the property diagram first, we might have been impressed with the great inequality of the income distribution. Quite a portion of the area is lost to view in the extreme height of the narrow vertical point, for the group of incomes above $5,250 represent over 13 per cent. of the total income, and they are absorbed by less than 1 per cent. of the people. But as compared to the property distribution, we see that the distribution of income among the masses is less niggardly. There is not the same great gap between the average income and the income of the middle man as in the case of property where the middle property was but 15 per cent. of the average. But the mean variation from the average is very high, being about 50 per cent. of the average. The average income is remarkably low, for in all incomes were leveled up, each family would receive but $1,480 ($300 per capita), which seems to be about what half of them are now actually getting, although some 40 per cent. are receiving less than half as much, while the remaining tenth might be accounted from middle class to exceedingly rich. The yearly income of our richest American citizen exceeds the life-time earnings of two thousand of our average American citizens. Mr. Rockefeller's income is about $100 a minute. His yearly income is roughly equivalent to the income of fifty average American citizens sustained through the entire Christian Era.

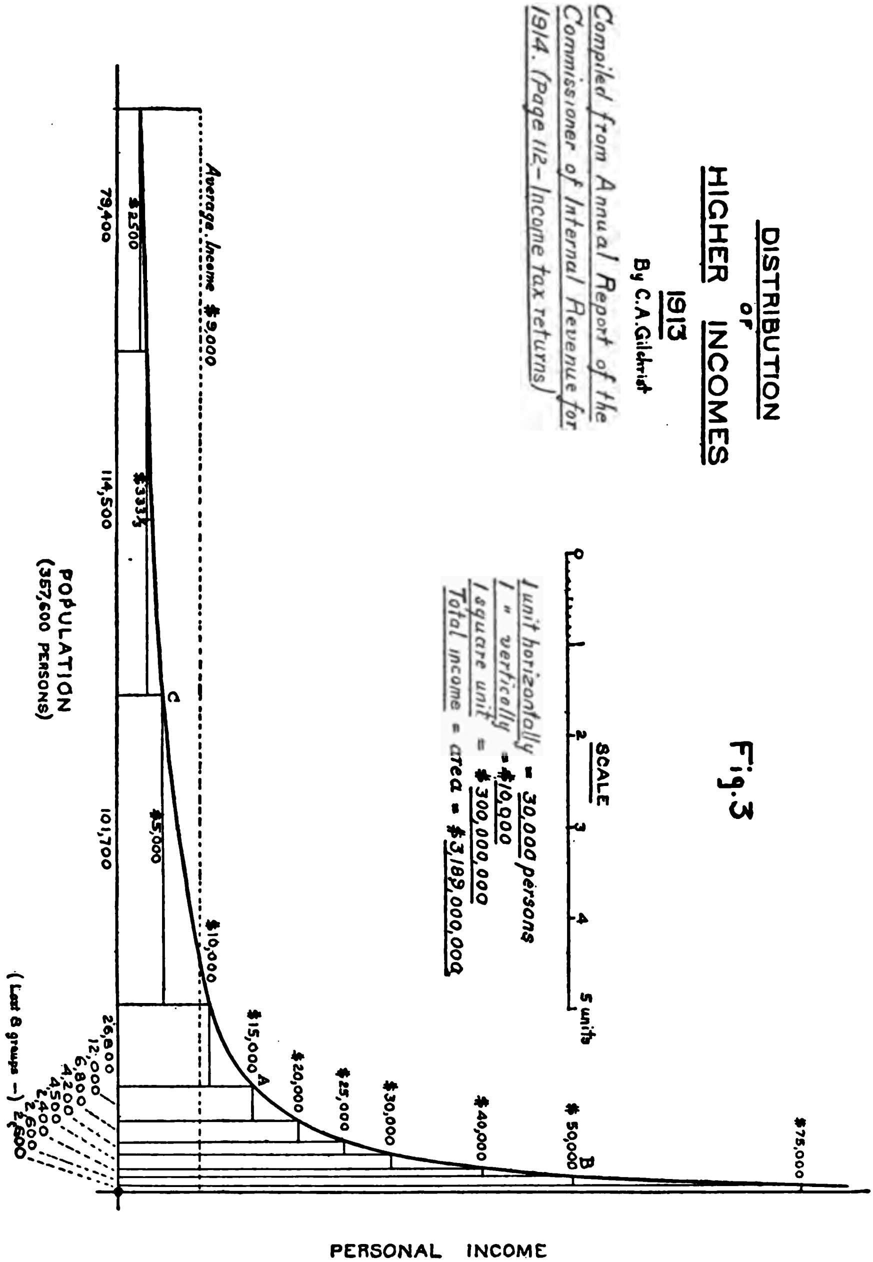
[3] Obtained by dividing the wealth represented by the total area between the curve and the dotted line by the number of families.

From Fig. 2 it would seem probable that the continuity of change in the higher incomes was continued down to incomes in the neighborhood of $1,600, but below that point the curve seems to change its nature, becoming much straighter. The cause of this probably lies in the fact that incomes, unlike property, can not fall below a certain minimum if life continues. This is what economists call an income or wage of "bare subsistence." For all incomes in the lower portion of the diagram the term wage, would, of course, be synonymous with income. Wages cannot fall below some such minimum because if the masses are to produce for the few, then the few must pay them at least enough to keep life going, even though they possessed the power to make them work for nothing. A man may possess power of life and death over his slave, but he will not get much out of him unless he feeds him. The nature of the horizontal limb of the curve clearly shows this principle. No such principle is illustrated in the curve for property, for a man may live without property, though he can not live without income, which makes it possible for the few to acquire *all* property. This the few actually do in a population made up mostly of chattel slaves, and Fig. 1 would seem to show that in effect this has been done in our glorious land of freedom to-day.

Although the figures and assumptions entering into these diagrams are extremely rough from a mathematical standpoint, nevertheless, the errors they involve can not affect the broad facts they display. The pitfalls of statistics do not lie in a failure to refine, but rather in a failure to interpret. Probably that group of family incomes where the distribution is least known is the group from $2,100 to $5,250. And the group where the distribution is best known is the group of family incomes from $5,250 up. This is the group of individual incomes from $2,500 up. Owing to the returns from the income tax, accurate information as to distribution in this high income group is obtainable, and it is worthy of separate consideration.

The Annual Report of the Commissioner of Internal Revenue for 1914 gives the number of persons receiving incomes in each of eighteen specified groups above $2,500. Owing to omissions that are discussed in the report, the incomes mentioned are all less than the actual incomes, but since the omissions would apply with approximately the same proportional weight throughout, the figures lose none of their significance as far as distribution is concerned. Fig. 3 is a diagram which treats these incomes as we treated all incomes in Fig. 2. It is the attenuated vertical point of Fig. 2 brought down to a horizontal and vertical scale that will make the distribution apparent.

When we remember that the statistics bind this curve much more fully than the curves of Fig. 1 and Fig. 2, there is something very striking about its continuity. So striking, in fact, that it makes us sus-


DISTRIBUTION
OF
HIGHER INCOMES
1913
By C. A. Gilchrist
Compiled from Annual Report of the Commissioner of Internal Revenue for 1914. (Page 112 – Income tax returns)
Fig. 3
SCALE
0 1 2 3 4 5 units
1 unit horizontally = 30,000 persons
1 " vertically = $10,000
1 square unit = $300,000,000
Total income = area = $3,189,000,000
Average Income $9,000
$2500
$3333
$5,000
$10,000
$15,000
$20,000
$25,000
$30,000
$40,000
$50,000
$75,000
A
B
C
79,400
114,500
101,700
26,800
12,000
6,800
4,200
4,500
2,400
2,600
2,600
(Last 8 groups —)
POPULATION
(357,600 PERSONS)
PERSONAL INCOME

picious of some general law of incomes displayed therein. In every one of the eighteen groups the mean rate of increase of the incomes is greater than the mean rate in the preceding group. It is not remarkable that the incomes continually increase from left to right, for they were so arranged as a condition of the drawing—but it is remarkable that their rate of increase should continually increase. True, this was also the case in the other two diagrams, but the continuity of curvature was not so marked and in the case of Fig. 1 we were free to make the curve fairly smooth, since we were bound to only two points. But here we are bound to eighteen points, all of which lie on a strikingly graceful curve.[4] Only ten of these eighteen points are shown on the diagram, the others all lying on the vertical limb beyond the limits of the drawing. But by plotting to other scales the same continuity is exhibited in all parts of this vertical limb. No manner of plotting will show satisfactorily the full extent of both horizontal and vertical limb at the same time.

What does this continuity of curvature mean? It means that incomes increase throughout their whole range at an expanding rate. In the fourth group the rate of increase is nineteen cents per person, while in the fifth group the rate is forty-two cents per person. In the first group the rate is one cent per person, while in the seventeenth group the rate is $2,280 per person. Or to put it in another way—a man in the seventeenth group, in order to raise his income by $2,280, must get ahead of but one other man in the race, whereas a man in the first group must pass some 228,000 others in order to raise his income by a like amount. It all means that the greater a man's income the easier it is for him to augment it—a state of affairs curiously incongruous, since the greater his income the less need for him to augment it. But this is the principle in distribution that accounts for the enormous inequalities of property shown by Fig. 1. It is what Herbert Spencer would call an example of the law of the "multiplication of effects." Or in current platitudes, "nothing succeeds like success." It would seem to show that a condition even approaching equality was one of unstable equilibrium and that society contains within itself the seeds of economic destruction. We do not assert that such is the case for there may be other seeds in society with an opposing tendency, but such opposing forces are not now, at least, in evidence.

[4] The curve in Fig. 3 has the general shape of the mathematical curve $xy^2 = a$. A curve of this form was forced to pass through the three points A, B and C by conditioning three of its parameters. These were the position of its two axes, and the constant a. If for coordinate axes we take the axis of X, .34 units below the horizontal base; and for the axis of Y, a line .039 units to the left of our right-hand vertical, then the curve $xy^2 = 3.85$ so referred, will pass very close to all ten points. At the $10,000 point it will be about .05 units too high, but at the other points the variation is too slight to show upon a drawing.

A summary of our survey points to the inevitable conclusion that the inequality of the distribution of wealth in the United States is violent beyond the dreams of avarice, and that its relation to human effort and ability is a vanishing quantity, while its relation to inequality of opportunity is most apparent.

With the opening of 1915 the wealth per capita was about $2,200, or, say, about $11,000 per family.[5] But these average or per capita figures are meaningless, since the property of the merest fraction of the people approaches anywhere near the average. The inequality in distribution is such that four fifths of the people own less than one tenth of the wealth, while 1 per cent. of the people own more than the remaining ninety-nine.

The annual production of wealth or annual income is about $300 per capita, or $1,500 per family, or $700 per person "gainfully employed."[6] If we subtract from individual incomes an amount not more than enough to cover the barest necessaries to physical existence, the remaining income or balance which "makes life worth living" shows an inequality in distribution on a par with that for property ownership.

The rate of saving, or rate of increase in property, is about $107 per capita per year.[7] Figures showing the distribution of this are lacking, but practically all the saving is necessarily with the few having the larger incomes. This follows directly from the expanding rate at which fortunes increase. If the annual addition to property was saved by the poor, then the poor would become richer and fortunes would tend to equalize instead of separate. Relative equality would then be a stable instead of an unstable state. The richer a man became the stronger the tendency to return to moderate prosperity. Such a state would be similar to all the faculties of man, such as thinking, walking, eating and so on. Any departure from the normal in these things is non-cumulative and sets up a tendency to return to the normal or healthy. And so it is with labor which produces all wealth, but not so it appears with the getting of wealth.

[5] Pro rated from the figures for the period 1904–1912. Census Bulletin "Estimated Valuation of National Wealth," pp. 15. The figures include every form of wealth down to dealer's stocks in hand, and household and personal effects—and exclude only such extremely transient wealth as value added to food by house wife, and personal services which are consumed as fast as produced.

[6] Persons gainfully employed includes only such as receive money for services and excludes a large class, for the most part of women whose services in house work while not translated into money value, is nevertheless exceedingly productive. The wealth created by this class is entirely consumed almost as soon as produced and since it does not enter into the circle of exchanges, it would be very difficult to estimate.

[7] Obtained by dividing the difference of the figures for national wealth of 1912 and 1910, that is, the increase in wealth in the two years, by 2, and by the mean population for the period.

Taking the per capita production at $300 and the per capita saving at $100, then the per capita consumption is $200 with the major part of the population consuming at a rate well below this figure.

In connection with saving it is interesting to note that while economists repeatedly tell us that interest[8] is the reward of *abstinence* or *postponed consumption,* practically all the saving is done by those few who are already rich, and to whom saving rather than abstinence, is sheer inability to consume. It will be objected that man's desires being unlimited, any portion of even the largest incomes that is not consumed must be accredited to abstinence. But this is to say that there is no objective standard of abstinence, and without this the economics of the case becomes impossible. If the poor man who curtails his food consumption in order to lay by for a rainy day does not abstain in a far greater degree than the millionaire who goes without a steam yacht—then the word abstinence has lost meaning. It is true that if a poor man is to become rich he must begin by abstaining, but, as he becomes richer, although he saves faster and faster, he abstains less and less. That is to say, the amount saved bears no relation to the amount of abstinence. The one is no more a function of the other than the heat energy liberated by a fire is a function of the energy expended in rubbing the match that started the fire. Of the capital or permanent wealth annually saved by the nation but an insignificant part can be attributed to abstinence. Here again we see the law of the "multiplication of effects" in almost sinister operation. The less necessity for saving the easier to save. Those that are rich must become more rich, while those that are poor will just subsist. Economic life to-day seems to be of the nature of a game in which the loser and the winner do not get the gains in proportion to their ability or effort, but the winner gets *all* the gains. This is strongly reflected in the phraseology of the day in which we speak of the "game of business," or when we speak of money-making as a profession or business in itself. Just as if carpentry was one trade and money-making another. A writer on economics in justifying large fortunes says:

> It is useless to decry the great American fortunes as the result of railway discriminations, extortion, oppression of labor, monopoly, etc. They are with hardly an exception the result of superior ability. We may criticize some of the methods, . . . but we can not deny that at the outset each one of Mr. Rockefeller's associates had the same opportunity to take this advantage of the railroads that he had, nor that his remarkable success shows conclusively his greater skill at the game of business.[9]

The opportunity here mentioned is not to produce, but to "take advantage." The truth of the statement lies not in the justification, but in the assertion of fact, the fact that skill of the kind mentioned does,

[8] Interest in the broad sense, as synonymous with property income.

[9] "Economics of Business," by Edward Sherwood Mead, Chap. VIII.

under present conditions, succeed in appropriating wealth that is the product of another kind of skill. If it is true that men are justified in having what they can get with the help of their brains, then the masses would be justified in having the wealth the rich now have, if they could get it from them.

The idea that interest is the reward for *postponed* consumption is as incongruous as the idea that it is the reward for abstinence. If I postpone consumption now I must indulge it later, for otherwise it is not postponement, but relinquishment. It follows that in any considerable period of time there can be no outstanding postponement, for the postponement of some will be neutralized by others who are vindicating their postponement by consuming. No man can be said to postpone to the extent that he leaves the world with wealth to his credit, for that is relinquishment. But the national wealth is increasing. The per capita wealth in 1850 was about $300, and now it is $2,200.[10] It means that the net saving has not come about through postponement, but through lifetime relinquishment. From the point of view of the nation we might call it postponement, but not from the point of view of the individual.

Unlike production and consumption, these things—saving, abstinence, postponement—are mere negatives, each is merely a *not doing*. They are induced solely for the purpose of fostering their opposite, which is consumption, the reality. A social science that bases its definitions on such abstractions must be illusive. Saving is undertaken for the sole purpose of furthering spending. If abstinence is undertaken for any other reason than to promote indulgence, then abstinence becomes insanity. If postponement is not vindicated, then it is not postponement. To this list should be added *scarcity,* a thing that—if we may call it a thing—has been responsible for profound confusion in economic thought.

The incomes we are discussing are, of course, real incomes, and these do not always appear in the prevalent method of bookkeeping and accounting. Thus, when a farmer produces food directly for his own consumption as well as for the market, the value of the food that he takes from his garden to his table will not appear as a part of his money income. But such value should be added to his money income to obtain his real income. The same can be said of value added by the labor of the housewife, and in fact of all wealth which is never appraised because it never gets into the circle of exchanges where relative values are measured by the standard monetary unit.

The distinction between property and service incomes, while usually apparent, is not always so. It is plain that dividends, interest and rent

[10] In spite of the fact that currency prices of standard commodities fell about 44 per cent. between 1866 and 1896, prices in 1911 were at about the same level as prices in 1850. The above figures are therefore comparable.

are always a property income, but in cases where an individual who uses property is also the owner, his real income appears on its face as wholly a service income, although it arises through the two different sources. Here are two men in all respects equal, and laboring upon two properties in all respects alike. But the one rents his property and the other is an owner. The books of the one will show that rent is paid to some third party to whom the rent is a property income. But the books of the other will have no such rent item. However, his income will be larger than that of the first man by an amount equivalent to the rent and this amount of his income is a true property income *even though it is produced by his labor.* Although his labor is precisely the same as that of the first man, and applied upon a precisely similar property, yet he has the advantage in the unequal ownership of opportunity. In a utopian state in which opportunity was equally divided, it might be well to change our definitions, saying that there was no property income and that service income was the actual product of the labor. But in the present non-utopian state the distinction is a necessary one, since our customs make possible the appropriation of a part of the labor product.

Various estimates have been made of the ratio between property income and all income. Nearing estimates that from five to ten billion dollars is the amount annually *paid* to owners of property in the United States. Five per cent. on all the wealth accounted for by the Census would yield a total property income for the year 1913, of about ten billion dollars. That the mean rate on this property is 5 per cent. is, of course, an assumption. The total annual income for 1913 is twenty-eight billion dollars as listed on Fig. 2. Bearing in mind that Nearing's estimate does not include income on property used by the owner, it would probably be near the truth to say that a third of all income was property income, and two thirds service income. Other estimates have placed the property income at 40 per cent. of the total.

Beyond the fact that property incomes come mostly to the wealthy we are able to say little about the relative distribution of the two kinds of income. Among those with small income there will here and there be cases of income which is nevertheless derived from property, such as the poor widow owning a few thousand in railroad shares. And among the wealthy there will here and there be cases of large income derived from service, such as managers, corporation presidents, and famous actors and painters. We must remember, however, that many high salaries which are apparently service incomes, are in reality property incomes which take the form of high salaries in order to conceal inordinately high returns on certain properties of an unusually monopolistic nature. But on the whole the bulk of property income will go to the wealthy because the wealthy are the owners of the bulk of property.

On broad lines the difference between property income and service income seems to come back to the difference between "wages of bare subsistence" and the balance that "makes life worth living." With full knowledge of exceptions it is generally true that the property income gives a man the whole of his time, which is freedom itself, while the service income debars a man any of his time save what is absolutely necessary for rest and upbuilding, and this is economic slavery.

In these days when public opinion is correcting our morals to make a place for great individual fortunes, much currency is given to the thought that such wealth is by its very concentration a benefit to all, as well as to the owner. The thought seems to be that concentration of wealth makes investment in large scale production possible, for divided wealth would tend rather to be consumed than invested. But if this is true we reply that it only indicates that consumable wealth is more needed than capital wealth, and if it is not true then large-scale production would go on with a highly divided instead of a highly concentrated capital. The fact is that the concentration of wealth is on this very account bad, because through the curtailment of the purchasing power of the masses, it is a distortion of effective demand, and through that a distortion of the direction which production must take. Demand or purchasing power is wealth, and where wealth is concentrated there is demand concentrated. The things that will be produced are the things that the owners of wealth demand.

The benefit or advantage of a fortune is the interest or property income it will bring, and that goes to the owner exclusively. If the fortune was owned by many, then the interest or benefit would go to many. If the fortune is owned by one, then the entire benefit goes to one. The great fortune may be looked upon in two ways, one in which the owner lives frugally and reinvests most of his income, and the other in which he consumes all of his income. The first is an increasing fortune and the second a stationary fortune. In the ethics of the case the stationary fortune is alone under consideration, for whatever we may say of it may be said with still greater weight of the increasing fortune at some future time. Whatever may be said of a thing because it is big may also be said of it because it is increasing. The fact that a rich man is not consuming his income does not mean that some one else is consuming it—his frugality is no sacrifice in favor of the people.

A popular excuse for large fortunes is the current notion that they "give employment." In the ownership of opportunity it may be truly said that the rich have employment at their disposal, but they do not *give* it. They sell it at the whole value of the opportunity, and the employed gets the product of his labor minus that part of the product made possible by opportunity—he gets "wages of bare subsistence." If instead of a few large fortunes most people had a moderate fortune,

then the total of employment and opportunity would be no less, but in addition to "no opportunity wages" most people would receive a moderate property income—most people would participate in the excess of production due to opportunity. The idea that great fortunes are excusable on the grounds of giving employment is conspicuous in the writings of Andrew Carnegie. He looks upon the rich man as if he held the property of society in trust, or merely controlled it, to be administered by his higher powers of discernment. He excuses the unearned increment on the ground that the rich as a rule reinvest it, thus giving more and more employment. There is a strong tendency in the literature of the day to substitute the word control for own. The rich may control much property they do not own, but that is not included when we speak of their wealth. Even where ownership is meant we are prone to speak of a man as controlling vast properties upon which thousands are working, as if he did not actually *own* it and personally derive every possible benefit from it as much as a child derives benefit from a stick of candy in hand.

But if service incomes that actually accrue are less than the wealth produced, are they less than the wealth produced by a proportional amount? Are service incomes *proportional* to the product? In view of the great complexity of labor interchange, it would be impossible to answer this in the light of statistics. Who, for example, would undertake to say just what value was added to production by the services of a locomotive engineer? The main force tending to an irrational distribution is undoubtedly property income, so that this eliminated, we might fairly say that service incomes tend roughly to become proportional to product.

But even if we grant that service incomes are proportional to product, we must not forget that the *ability* to produce depends upon how much a man participates in property income. It depends upon leisure and education. Grant that your laborer is a shiftless sort and does not really produce more than $1.50 a day, still, were he the possessor of a small property income, his increased income would be enough to increase his ability to produce and thus increase his service income as well. The differences in what men do produce is vastly greater than the differences in their latent abilities. That among those born in poverty to die in poverty a large portion never produce much through lack of opportunity for development of productive powers, is evidenced by the dramatic cases of one born in poverty risen to be one of the world's most productive workers, Andrew Carnegie himself being such an example. If the seeds of these high productive powers were implanted only in a very limited portion of the human stock, then we should expect the children of the founders of fortunes to be the only fortune-makers. But this is precisely contrary to the facts. The riff raff of Great Britain

go to Australia, where opportunity develops their latent powers, and in a generation they are the leading citizens of the land, while the offspring of our rich men, if they succeed in maintaining their inherited fortune at all, are notably lacking in productive powers through a surfeit of opportunity, or a lack of something which only the feeling of a little of the pinch of necessity can supply. Thus, while service incomes may approach somewhere near a distribution in proportion to the wealth that the service actually produces, such a distribution is far from just, because the deduction from service of the income that goes to property is a deduction from productive ability itself. If property were more equally distributed, *because of that* production would also be more equally distributed.

The picture we have drawn is a depressing one. It is the more depressing when we remember that the question of wealth is the most important question in men's lives. An elect few who are neither rich nor poor have solved the problem of wealth, but not so with most.

> The fear of poverty makes us admire great wealth; and so habits of greed are formed, and we behold the pitiable spectacle of men who have already more than they can by any possibility use, toiling, striving, grasping to add to their store up to the very verge of the grave.[11]

But the picture is not so depressing when we compare society as it is with what it may be.

> Did you ever see a pail of swill given to a pen of hungry hogs? That is human society as it is.
>
> Did you ever see a company of well-bred men and women sitting down to a good dinner, without scrambling, or jostling, or gluttony, each knowing that his own appetite will be satisfied, deferring to and helping the others? That is human society as it might be.[11]

[11] Henry George, "Social Problems," Chap. VIII.

CAN A COLLEGE DEPARTMENT OF EDUCATION BECOME SCIENTIFIC?

BY JOSEPH K. HART

DEPARTMENTS of education in colleges and universities have been made the objects of a good deal of more or less good-natured criticism and some ridicule within recent years. For example, Professor Gayley has denied the utility of such departments altogether, declaring that teaching is "a profession that demands not so much method as scholarship and innate aptitude."[1]

Professor Warner Fite, too, has taken occasion to express a rather definite view of the same sort. He says:

> What the public school teacher especially needs to learn, and what the university is especially called upon to teach him, is just this—that his real efficiency as a teacher, and his ability to speak to his boys and girls from the standpoint of personal and social authority, will depend in the last analysis, not upon any mastery of the "formal principles of method," or what not, but upon the evidence in himself of a thoughtful attitude toward life.[2]

What such writers are attempting to demonstrate is, of course, largely true, though expressed in intolerant terms. Departments of education, as distinguished from schools of education and teachers' colleges, have not yet fully found themselves. Educational theory is, on the whole, becoming rather securely based. But in its practical outcome it does not always realize its own inner logic and, therefore, falls under the criticism or ridicule of those, who, working in older and better established fields, sometimes forget the ways over which their own subjects won to recognition, and express themselves in terms not altogether worthy of scientific men.

Dewey's estimate of the function of such departments seems more nearly correct. He says:

> That some teachers get their (theory) by instinct more effectively than others by any amount of reflective study may be unreservedly stated. It is not a question of manufacturing teachers, but of reinforcing and enlightening those who have a right to teach.[3]

Why, then, have departments of education been criticized in this way? There are at least three reasons.

In the first place, criticism has been the fate of all new departures from tradition, of all new movements. It is natural, normal and necessary for the proper organization of the new departure and for the prun-

[1] "Idols," p. 138 ff.

[2] Fite, in *The Nation*, Vol. 93, p. 207–8.

[3] Dewey, "Psychology and Social Practise."

ing off of all extrinsic and useless elements and characteristics. Any innovator must expect and must welcome this treatment.

In the second place, the department has inevitably inherited and brought into the university some of the flavor of the normal school, and has suffered somewhat from this fact. Originally, in many schools, the department went under the name of "Pedagogy," and this "blight" has not yet been completely cured. The significance of this will appear in the next statement.

In the third, and most important, place, the department of education has been severely criticized because it has not, everywhere, fully caught the spirit of science. The spirit of the modern university is, on the whole, scientific. The department of education is one of the youngest of university departments. Coming into the university by the sufferance of the older departments, its place in the university must depend upon its ability to win the respect of these other departments, in which the spirit of science largely prevails. This has not always happened.

In some of the larger schools of education and teachers' colleges extensive differentiation of work and a considerable development of the spirit of inquiry have appeared, at least in certain lines. But in the colleges and universities where this work is still carried on within a department, there is large foundation for the suspicion that little work of a genuinely scientific character is done. It is probable that a thorough inquiry would reveal similar conditions in many departments which pride themselves upon their scientific standing. But that is aside from the point. Our question is: Can a college department of education really become a scientific department?

This question takes two directions: first, what is the real work of such a department? and second, can such work really take upon itself the scientific spirit? These are, however, not two distinct problems: the first suggests two answers and appeal must be made to the second for a decision as between these two.

What, then, is the real work of the college department of education? The two answers, suggested above, may be called, without invidious distinction, the intellectual and the social programs in education. (Such a distinction appeared in a recent discussion of this subject among a group of teachers of psychology and education in certain colleges and normal schools.)

The answer, which is here called intellectual, seems to conceive the educational situation somewhat as follows: The school exists as a fixed institution having the task of training the children of the community. The curriculum of the school is pretty clearly defined; the methods are, in the main, well worked out; the constructive principles to be obeyed are in the books; the machinery of administration and control is established and in working order.

From this point of view, therefore, the work of a college department of education will be the training of teachers to fit into this existent school situation. Such training will linger long on such courses as the "Principles of Education," "Methods," "Child Study," and the like; with, if possible, some practise work in the school system. In all of this the effort will be made, in very sympathetic ways, to help the prospective teacher realize the conditions of school-room procedure, and the appropriate ways of doing things under all circumstances. A course in the history of education may be offered, or required, but, if so, its function will be largely informational. So, also, courses in the social aspects of education or theory of vocational education, and the like, may be offered; but these will be for the purpose of making sure that the prospective teacher knows what is going on, and is properly fortified with arguments against the educational fallacies of the age.

In it all there will be little, if anything, deliberately intended to stir the native hue of intelligent resolution in the prospective teacher and make him feel his own creative and constructive responsibility in the educational tasks of his community. The argument will even be advanced that children must have a larger freedom of opportunity and initiative in education to-day; that the school must learn how to offer this greater freedom; and that therefore the teacher must have a more complete training. But the training must be of this "safe and sane" sort: it must acquaint him with assured results, so that he will fit into the institution.

Or, if there be some work offered in the field of experimental education, it partakes largely of the nature of the alchemy of the middle ages. It is pseudo-scientific. It looks for curious facts. Assuredly, it is not for the purpose of stimulating such a spirit of intelligent inquiry as might make the student independent of the teacher—a free citizen of the realm of science.

That is to say, the whole effort of departments of education organized from this point of view is traditional, rather than scientific. Their spirit is really that of the old time normal school—wherein teachers learned how work was to be done: the knowledge was existent; the student "took it on."

But what is the real spirit of science? Whatever else it may be for other departments or in other fields of life, in the field of the training of teachers, science can mean but one thing: the development in the prospective teacher of the spirit of inquiry and the method of the investigator. This will involve the growth of knowledge, of course; but it will be knowledge, not as an esthetic possession, but as a tool of analysis of the community's life and need. It means not mental certainty and satisfaction, but mental alertness and the open mind.

Is it possible to organize a program for a college department of

education that will develop this outcome? Such a program, set over against the intellectual and traditional one described above, may be called social, and will, of course, be worthy of the name of science. And this outcome can be secured.

Such a program will accept the propositions that the pupils in the schools must have a larger freedom for constructive self-activity and creative self-expression; and that teachers must be prepared to organize schools that will provide such opportunities. But such a program will recognize this fact, seemingly overlooked by the traditionalist, that the teacher, who is to provide freedom of initiative for pupils in the schools, may rightly claim something of the same freedom of initiative while in preparation; that, therefore, the work of the department of education, instead of being more rigid and fixed, should be more open and free; planned, not to *finish* the student's mental life with fixed answers and final attitudes, but to make that mind more alert, more independent, more able to recognize problems, more capable in the raising of new questions, more able to discern the valuable from the trivial, more efficient in the analysis of conditions and in the selection of solutions. In a word, the department of education will aim to secure in its students (who are to be the teachers of the future) the development of the powers of effective, analytic, and constructive thinkers. Angell analyzes this power as follows:

> Our effectiveness as practical reasoners (or theoretical reasoners, for that matter) will depend then, first upon the skill with which we succeed in *conceiving* the problem correctly, and second, upon the speed and accuracy with which this conception suggests to our reasoning processes the recall of the special ideas appropriate to the case at hand.[4]

A department of education that wants to be scientific will, then, train its students to look for *problems,* not *answers;* for the growing educational situations, not the finished conclusions; and for the larger and inclusive conditions of education, rather than for the finished details of a traditional educational craftsmanship. Science believes in intelligence: when the problem has been clearly stated and conceived, the solution is not far away, and can be expected to follow in due time. It is not the business of the teacher to supply *answers;* enough that he helps the pupil to grasp the problem!

The purpose of the department, therefore, ought always to be to stimulate the mental life of the pupil (the future teacher) rather than to deaden that mental life; to release the energies, the imaginations, and the deeper appreciations of the student rather than, by cramming the student with the results of investigations in various lines, to make his mind more sodden and inflexible. For the purposes of this problem-developing type of training, four general introductory lines of work, which have a certain logical relationship to each other, are possible.

[4] Angell, "Psychology," p. 281.

According to this social program, the first line of work to be taken by teachers in training, should be a course in the history of education. This will be, not a course of the traditional kind, wherein a long series of historical events is considered. It will be a course, not for the purpose, primarily, of coming to know the history of education; but for the purpose of uncovering the roots of the present problems of education and getting a genuine perspective of those problems in their historical development. For, history is not ended, and we are not at the end. We are in the very midst of the history of education, with problems all about us, with tasks all unfinished, and, if we could but see, with the need of programs and reconstructions that will run ahead into the far future.

The large problem of education is the making of new educational history. The real reason for studying the history of education is that one may learn how to become a maker of history. For this purpose, history must awaken the mind of the student to the problems, forces, and conditions of the present; and its outlook must be towards the future. Such a course will have scientific validity in that it will seem to the student to be the consideration of real problems and it will make him more alert and awake to realities, not merely of the past, but of the present and the future. He will finish the course with a sense of the problems of education that he must meet.

Upon the basis of such a digging up of problems, it is possible to build up a course that will organize all these problems, institutions, forces, and conditions of the present into what will be a cross-section of the history of education, to be called "The Social Aspects of Education." Here will be raised the questions of the social sources of the experiences of children; the nature of community life within which these experiences go on; the elements that may be lacking or exaggerated in the life of the community; the relationships of our social institutions to the development of intelligence in children; the place of industry and the industrial organization; of play and the play life, of religion and religious institutions, and all the other social forces in the actual education of children.

It will raise the question as to the real work of the school in the light of its historical development, and in the midst of other social institutions. It will develop the problem of the community's own edution, and the part that the community's general life plays in the education of its boys and girls. And it will, finally, develop the universal problem, "why does so large a part of our school-inculcated intelligence fail to make any useful connections with the actual life of the community?"

This last question will set the problem for a third general introductory course. That problem, stated more fully, is this: How can we de-

velop an intelligence that is predominantly social, rather than, as at present, intellectual and remote? This problem seems the task of a course in the social psychology of education. We have to-day many psychologies of education. Some of these are merely moralizing restatements of old analytic psychologies. Others are socially useless statements of the results of modern laboratory research. An experimental chapter on memory is a valuable piece of work, and should be found in this social psychology—as a sort of footnote. This social psychology will be conscious of the social source of all educational experiences and it will look ahead to their social outcome. It will make use of laboratory results in stating the pure mechanics that may be needed in the processes of training. This will give meaning to laboratory material, most of which is confessedly of no use at present to any teacher—from which, indeed, teachers have been rather severely warned—and this use of laboratory material will save analytic psychology from mere moralizing.

Beginning with the social conditions of experience and keeping always in mind the social outcome of experience, such a course as this should work out the main psychological pathways by which children may be assured a gradual development of a genuinely intelligent experience, without at the same time losing the social quality, either of their experience or of their intelligence. This course, therefore, ought to offer to the student an effective psychological instrument for the analysis in social terms of the educational problems that will present themselves in the school room and community.

In the fourth place, there should be required of all students who expect to teach, a constructive course in the social principles of education. This will probably involve either previous experience as teacher or parallel work as practise teacher. In this course the students should do all the work. The teacher's function will be merely to keep constantly fresh, and stimulatingly active before the minds of the students, the question: "What shall be my program as a teacher in the school?" The history of education has given the perspective of present problems and conditions; the social aspects of education have given the broad, social outlook and the conditions within which the program of education must go on; the social psychology of education has analyzed, as much as may be, the methods and processes of a social intelligence. And on the concrete basis of previous experience or present practise, the student should now work out a constructive outline of his intended program as a teacher. This program should consist of the student's own individual organization of all his previous training, experience, study and intelligence, into a hypothetical plan which will sum up his present understanding and determination.

In this course, he should become conscious, as never before, of the

social background of his future educational work and of the significance of human culture and the educational sciences for his methods and program in the school. He should be able to say, at the end of such a course, that he has found *himself,* not merely his teachers, or some books, and book answers. The principles which he carries away with him should be his own, wrought out in his own intelligence, and expressing his own capacity for service in the world.

This program, the expression of his own personality, should enable his instructors to determine more definitely his probable value as a teacher: whether he has, or can attain, that actual intelligence and power of performance which will make him a constructive force in his future school community, able to *recognize and analyze problems,* capable of self-expression and initiative, and therefore capable of welcoming and developing the self-expression and initiative in the children whom he is to teach.

There will be many other particular phases of the field of educational theory and practise which the prospective teacher will want to investigate: advanced work in theory, principles of administration and supervision, special problems in psychology, and various aspects of the social side of educational development. These should be provided for with such freedom as will permit the further extension of the student's intelligence into the eventual sense of mastery of education as a social function.

There is another aspect of the work of such a department to which attention must turn for a moment. This is the field of constructive research work, for the most part the task of the instructors in the department, with perhaps the help of advanced graduate students. From the point of view here presented this research work is inseparable from the work of training prospective teachers. At the present time, or up until the present, research work in the field of educational theory has been largely devoted to the special investigation of problems in psychology. It has seemed that this part of the field was the only part possessing sufficient scientific dignity to warrant reputable research.

But this would seem to be a mistaken view. The great field of research in educational theory may yet come to be found in the social sources of educational experience. Let this be illustrated concretely. Education is a social function. It begins with the children of the community, it proceeds in the midst of the community, its outcome is to be the community of the future. Not all of education goes on in the school. President Wilson's recent statement that "the government can not generate thought" is true also of the school: the school can not *generate* thought. Experience, thought, emotion, appreciation: these are all *social* products, not the products of the schools. At the best the schools can create the conditions under which these products appear, and can criticize them, and organize them as they do appear.

What, then, are the resources of the community in these directions? Just as the geologist surveys the state, looking for its possible supplies of mineral wealth, or just as the forester searches out the remote resources of lumbering wealth, so the educational research men of the future will explore and survey the state for its hidden wealth of moral energy, youthful idealism, social purpose and individual promise hidden in village or city homes, working in quiet ways in the making of better communities, struggling with the untoward elements and crudities of social life everywhere. The state is rich in these hidden resources: men and women, especially young men and young women, and groups of all these, who are working with zeal and hope, yet with much indirection, for larger and better things. The school must get over its academic tradition and get into an attitude of mind that will enable it to understand, appreciate, and give really intelligent direction to these partial movements. *These* are the real educational resources of the state. Here the future teachers will find their problems, their inspirations, and, if they have been trained to the development of a native intelligence, the tasks of life.

These are the real problems of educational research. How can our schools make organic connection with the educational hopes and purposes of their own local communities, and bring to those communities the intelligent direction that they lack, that they long for, that they must have, yet of which they are self-respectingly and narrowly suspicious? How can these things be done? These are the tasks of that larger educational research that is opening before us, to-day. Here open the problems in educational psychology, not of the dry-as-dust sort, but of the vital, social sort, whose results when found will have significance for education elsewhere. Here are the calls for long and intelligent consideration by all the men and women who can be found. And results attained in these fields will have scientific value, social value, and practical value in the training of teachers.

Other aspects of this problem should be presented, but these phases of it show the scientific possibilities hidden in this field. Such a program of teacher-training, and educational research might win for the department the scientific standing that it longs for among the departments of the university or college. At any rate such a program would indicate that the department had caught something of the spirit of real inquiry, the real spirit of science, and that it could really become scientific.

NEW JERSEY'S INSECTS

BY HARRY B. WEISS

NEW JERSEY AGRICULTURAL EXPERIMENT STATION

INASMUCH as the number of species of insects inhabiting the earth is far greater than that of all other animals grouped together, it is hardly necessary to state that New Jersey's 10,530 species should not be taken as an indication that this state is an undesirable place in which to live. Other states have just as many, if not more. As the presence or absence of insects within the borders of a community or state may be responsible for the difference between sickness and health, irritation and comfort and poverty and wealth, the following questions naturally arise when such a large number of species is considered. Are all of them injurious? If not, of what use are the others? Are any of them beneficial and so on.

The following tables compiled chiefly from Smith's "List of the Insects of New Jersey" and other papers dealing with the insect fauna of that state will serve to answer these questions. Ten thousand, five hundred and thirty is the number of species which has been recorded up to the present time. Many others, principally in certain obscure groups, remain to be found, but, on the whole, New Jersey has been rather well collected over and the above number is fairly representative. The eight divisions used are those in which the species naturally fall. It would be possible of course to have a larger number of groups, but for a clear and quick understanding, a few only are desirable. Those insects whose habits vary considerably in the different stages have been placed according to their predominating mode of life.

The first group includes those of little or no economic importance, such as species of the *Corrodentia* which feed principally on lichens and moss, and the aquatic forms found in the *Plecoptera, Ephemerida* and *Trichoptera.* The second includes various species which infest stored products, food and otherwise, and those commonly known as household pests. The scavenger and third group embraces the feeders upon the products of decay, dead or dry animal and vegetable matter, and those which change or remove the form of animal and vegetable remains and aid in reducing such substances into shape for assimilation by plants. The fourth division consists of those which annoy, irritate or transmit diseases to vertebrates, while the fifth takes in all which are predaceous upon other insects. Those which feed upon liv-

ing plant tissue, many of which are of direct interest to the agriculturist, will be found in the sixth group, the insect parasites in the seventh and the beneficial plant feeders or pollenizers in the eighth. It would be possible of course to include in the eighth group, certain members of the Diptera, Coleoptera and Lepidoptera which as adults serve a useful purpose as pollenizers, but, on the whole, such species have other predominating larval habits which overshadow the beneficial ones of the adults.

Table I. shows how the different orders are represented in each group.

TABLE I

Order	1	2	3	4	5	6	7	8	Total No. Species
	Of No Economic Importance	Injur. to Stored Products	Scavengers	Injurious to Vertebrates	Predatory	Injurious to Vegetation	Parasitic upon Insects	Beneficial Plant Feeders	
Thysanura		3	38						41
Ephemerida	29								29
Plecoptera	25								25
Mallophaga				101					101
Isoptera			1						1
Corrodentia	36	2							38
Platyptera	9								9
Neuroptera					44				44
Mecoptera					11				11
Trichoptera	60								60
Odonata					121				121
Thysanoptera						14			14
Parasitica				13					13
Homoptera						507			507
Heteroptera				2	142	269			413
Dermoptera	5								5
Orthoptera		3			9	140			152
Lepidoptera		4	25			2,091			2,120
Coleoptera		44	1,161		696	1,207			3,108
Siphonaptera				4					4
Hymenoptera		2	118		302	362	1,012	211	2,007
Diptera			475	133	357	485	257		1,707
Totals	164	58	1,818	253	1,682	5,075	1,269	211	10,530

TABLE II

	Per Cent.
Insects of no economic importance	1.55
Insects injurious to stored products	0.55
Insect scavengers	17.26
Insects injurious to vertebrates	2.40
Predatory insects	15.97
Insects injurious to vegetation	48.19
Insect parasites	12.05
Beneficial plant feeders	2.00

Table II. indicates the percentages of the different groups. Thus 17.26 per cent. of all the species found in New Jersey can be classed

as scavengers, these being found principally in the orders Coleoptera and Diptera. Belonging chiefly to the Mallophaga and Diptera, we have only 2.40 per cent. which are injurious to vertebrates, among which however are species closely associated with man and disease. In the Coleoptera, Hymenoptera and Diptera are found most of the predatory forms, amounting to 15.97 per cent. These, of course, are engaged in feeding upon and destroying those of their kind and others which might be more or less beneficial. The largest percentage, 48.19, consists of insects which injure vegetation and is made up chiefly of species from the Lepidoptera, Coleoptera and Homoptera although some of the other orders are fairly well represented. In the parasitic group, the 12.05 per cent. is found solely in the Hymenoptera and Diptera. Classing the scavengers, the pollenizers, the predatory and the parasitic forms together, we have a total of 47.28 per cent., a number which almost equals the percentage of injurious ones. Thus it is seen that almost one half of the species of insects which we have in our midst are engaged in useful activities.

Considering the injurious ones from another viewpoint, namely, that of destructiveness, it is surprising how small a proportion is destructive enough to warrant the application of insecticides or remedial measures. The following table (III) gives the total number of species in the seven most important orders and the number and percentage of destructive ones. It must be remembered, of course, that there are numerous other species classed as injurious, but these do not occur in sufficient numbers to make their presence felt or they confine their attentions to unimportant plants and are therefore not included in the list.

TABLE III

Order	Total No. Species	No. of Destructive Species	Percentage of Destructive Species
Coleoptera	3,108	50	1.60
Lepidoptera	2,120	58	2.73
Hymenoptera	2,007	9	0.44
Diptera	1,707	28	1.64
Heteroptera	413	8	1.93
Homoptera	507	28	5.52
Orthoptera	152	5	3.28

Of the entire number of species listed from New Jersey, 10,530, which includes all orders, only 1.76 per cent. is really destructive. Of the entire number in the seven orders in Table III., only 1.85 per cent. is destructive. As to the individual orders, the Homoptera have the largest percentage and the Hymenoptera the smallest, which is not strange considering the fact that all of the members of the Homoptera are plant feeders, while the Hymenoptera consist of both beneficial

and injurious forms, with the former largely in the majority. The Orthoptera with its 3.28 per cent. of destructive species contain a large majority which feed upon vegetation. While most Lepidopterous larvæ feed upon vegetation, yet the fact that many confine their activities to plants not under cultivation by man or occur in small numbers, brings the percentage down to 2.73. The Heteroptera are plant feeders with numerous exceptions; predatory and injurious insects are abundant in the Coleoptera and the Diptera contain predaceous and beneficial species as well as feeders on animal and vegetable tissue. In these three orders, the percentages of destructive species are similar.

Therefore, the insect losses in the state of New Jersey are due entirely to the activities at different times of only 186 species, some of which are and any one of which may become notably abundant.

THE HISTORICAL CONTINUITY OF SCIENCE

BY PROFESSOR T. BRAILSFORD ROBERTSON
UNIVERSITY OF CALIFORNIA

Yet I doubt not thro' the ages one increasing purpose runs,
And the thoughts of men are widened with the process of the suns.
—Tennyson.

FROM the time that man first entered upon those labors which were to earn him that rich heritage of civilization which we own to-day two groups of objects presented themselves to his senses and his intelligence, each demanding, for sheer self-preservation, the closest study his intellect could furnish. The one group comprised his fellow-men, the other the sum total of objects and phenomena which comprised his non-human environment. From the study of the former group arose the juridical and political institutions of man, while from the study of the latter group arose his religions and his science. The motives urging him to these studies were the primeval instincts of self-preservation and curiosity, but unanticipated advantages accrued therefrom to the most successful students; from the first group of studies sprang the conquest, subjection and exploitation of less gifted or less fortunate members of his species, while from the second group of studies sprang the conquest and the interpretation of nature.

In one of his classical essays Huxley, for the purpose of expounding and illustrating the methods employed in his chosen field of investigation, has told us the story of Zadig, an illustrious philosopher and astrologer of ancient days, who by the minute observation and comparison of facts which were at first sight unrelated, was able to trace and restore to his imperial master the favorite horse and dog, the loss of which had constituted a national calamity the magnitude of which may well be imagined. But the illustration which was thus employed by Huxley to describe the methods of investigation employed in one particular field of scientific research might equally well have been employed to illustrate the discipline of thought in any other field of investigation. *Observation, comparison, deduction* and *trial* the success or failure of which inspires and directs further observations which form the starting-point of a new and wider cast of his net into the sea of the unknown, these are the successive steps in the discipline of thought which has slowly and inevitably led man from helpless dependency upon the caprice of nature to the present day when his words travel with the speed of light and his instruments pierce the depths of interstellar space.

The historical continuity of science and its origin in curiosity and the instinct of self-preservation seem in general to have been overlooked by scientific investigators and historians of science, and there are even certain authorities who, in complete forgetfulness of the fundamental canon of the scientific method enunciated by Newton, have urged that science can not be said to have begun until "laws of nature" had been formulated and the "causes" of phenomena ascertained.[1] But that is to invert the real evolution of scientific thought. As man's field of observation and comparison grew wider his deductions grew wider, until at length they became bounded only by the limits of the visible universe, but deductions are not knowledge, inferences are not science, they are merely implements which we wield for the further attainment of knowledge, the incitements to further research.

From the earliest dawn of history we find man formulating universal generalizations which he has deemed laws of nature. His intellect demanded knowledge which his feeble powers were not yet fitted to attain, so by a simple extension of the method of anticipating results which he employed in investigating the minor details of his accustomed environment, he launched out into the infinite and anticipated the totality of phenomena. These deductions formed the dogmatic bases of his religions, and since from their very nature they could not be subject to the control of trial to which his less exalted generalizations were required to submit, so trial became taboo and the acknowledgment of impotence was deferred by making a virtue of necessity and faith an attribute of piety.

But, our scientific historian may here exclaim, our laws of nature are true, and the fantastic imaginings of primeval man bore no necessary relation to fact. I would reply that all truth that is known to man is relative and that primitive religion bears exactly the same relation to fact, upon a narrower basis of knowledge, that our laws of nature bear to our wider knowledge of fact. They were the best generalizations that the profoundest and most inspired intellects of their age could form upon the basis of their then knowledge of the universe. Our generalizations represent no better efforts or manifest superiority of our intellect, they are the fruit of wider opportunities, but they do not therefore necessarily constitute the truth. There are certain curves well known to mathematicians, which, while they continuously approach a straight line, yet no matter how far we may trace them, short of tracing them to infinity itself, never actually attain the line. So with the knowledge of man; it is asymptotic to the Absolute, and continuously approaches but never attains the truth. Thus, while I do not deny that the law of the conservation of energy bears a closer relation to objective reality than the cryptic utterances of the Delphic oracle,

[1] For example, E. Ray Lankester, "Degeneration, a Chapter in Darwinism" in "The Advancement of Science," London, 1890.

yet the very universality of the generalization sets it apart from the actual knowledge, acquired of our senses, and places it in the realm of super-sensual belief.

Belief is not science, but the beliefs of man and the science of man are destined to develop as they have developed in the past, side by side, products of the same instinctive need, often apparently antagonistic because they approach the same infinitely distant goal from widely divergent angles. But as science asymptotically approaches the Infinite, so will religion approach science, until, when the intellect of man shall become commensurate to the totality of being, the two modes of interpretation will find at last their meeting-place in regions infinitely remote from the little knowledge of our day.

When we look back to the dawn of history and of written science we find man already advanced to a very comprehensive understanding and control of his environment. His conceptions were embryonic in comparison with ours, just as ours are but the germ from which will spring the ripe fruit of the knowledge of a thousand generations hence. Nevertheless in climbing the barrier which separated him from the Absolute, man at the dawn of history did not have to start from the level of utter ignorance and impotence. Far from it, for he had already attained a wide and inspiring outlook which only appears narrow to us to-day because we are vouchsafed an outlook so vastly more comprehensive that our larger perspective diminishes the vision of our ancestors to the dimension of a negligible proportion of the area which is now unfolded to our view. But in all the achievements of man "c'est le premier pas que coûte" and we, whose achievements will appear to our descendants so pitifully puny, can not afford not to pay our meed of profound respect to the accumulated product of the primitive facilities and unremitting toil of those who after all are removed from us in time by but an infinitesimal moiety of the eons which have been consumed in the accomplishment of our development.

Let us endeavor briefly to retrace a few of the most significant steps by which man attained that degree of knowledge and control of his environment which permitted the foundation of barbaric empires, the rise of which marks the dawn of recorded history.

The first essential step in this laborious ascent was the development of the tool. With his hands aided only by intelligence man could accomplish little more and in many directions of his endeavor less than many of the organisms which were directly or indirectly his competitors in the struggle for existence. Those concatenated reflexes which we term instincts were very much less elaborately developed in man than in many other inhabitants of his environment, a fact which was ultimately to his great advantage since his simple and primitive instincts were, by reason of their comparative simplicity, flexible and

adaptable to the vast variety of material and social environments in which man has by turns found himself situated. But in the early stages of his struggle for the mastery of nature the lack of elaborate instincts, such as those which enable the social hymenoptera to achieve such prodigies of skill and organization without the necessary exercise of any intelligence whatsoever—the lack of these placed man at a definite disadvantage. Physically not of the most powerful type and unassisted by elaborate instincts, he was compelled to supplement his deficiencies by the superiority of his intellect. Extension of his physical powers was the first prerequisite for supremacy, and this extension was afforded by the invention of the primitive tools, piercing, cutting, hacking, grinding and pounding instruments which multiplied the effectiveness of his physical powers by many thousand-fold.

The origin of the primitive pounding and grinding instruments is not far to seek, the first glimmerings of associative memory sufficed to provide us with these, as witness the fact that many animals and birds employ them. The cutting, piercing and hacking instruments demanded much more accurate observation, comparison, deduction and trial for their elaboration. In the beginning fortuitously encountered, the chance supply of ready-fashioned instruments would speedily be exhausted, and then it was that true inventiveness was called into play. First it must have been observed that certain types of stones yielded sharp edges while others did not, then that blows upon these stones produced cleavages and that some of these cleavages were sharp-edged and others were not, and finally by incessant trials sustained by inexhaustible patience and unflagging acuteness of observation, the correct type and direction of blow was ascertained which would yield a satisfactory instrument, a stone axe or an arrow-head, with an expenditure of time and labor which, although from our present point of view immense in proportion to the result attained, was nevertheless practicable and infinitely valuable in its outcome.

The first reliable hunting instrument must have been the spear and doubtless in many instances, as in the case of the living survival of neolithic man, the Australian aboriginal, the effectiveness of the spear was aided by throwing it at the object which was assailed. The customary killing of large animals yielded three very important results, first it increased the supply and variety of available food, secondly the skins (first assumed probably in imitation of the animals slain, in the performance of some obscure totemic rite) afforded clothing and increased enormously the possible geographic range of man, and thirdly the use of the sinew was discovered.

The utility of the sinew as a means of tying and binding may have been largely a fortuitous discovery, but what are we to say of the discovery of the bow? It should be observed that the bow is useless until

it is complete. The spear or arrow may be imperfect and yet admit of being impelled towards its object, but the means of impulsion embodied in the bow must have been completely developed and its purpose foreseen before its enormous utility could by any possibility be demonstrated. When we reflect upon the limited facilities and pitifully imperfect instruments of primitive man, upon his almost utter lack of experience of propelling instruments or indeed of any other kind of instruments, and of the conservatism imposed upon him by tribal ritual, we must I think admit that the discovery (or perhaps repeated rediscovery) of the bow is an unassailable proof of the existence among our primitive ancestors of men the creative vigor of whose intellect and capacity for taking infinite pains could not be surpassed by any of the investigators and inventors of our own epoch.

The power of man as a destructive agent was enormously enhanced by the discovery of the bow; no proportionate increase in destructive power was ever to occur again in his history until the day of the discovery of gunpowder. But power to destroy was not enough, the power to create was needed to supply its complement. Unchecked destruction implied ever increasing labors of the chase and automatically enforced a limitation to the human population of any given area, as happened, for example, in the areas inhabited by the North American Indian. But side by side with the rise of man's destructive power arose his constructive abilities, and it is in the means he chose and the success he achieved in his endeavor to provide a certain and predictable supply of animal food that we recognize some of the most striking evidence of the flexibility and adaptability of the intellectual weapon which he had begun to fashion for the conquest of nature.

The domestication of animals demanded minute observation of their habits in order to acquire that sympathy with their requirements which was an indispensable factor of success, and this knowledge acquired, the patience which was exerted in applying it must have been of an order which in our age of facile mediocre accomplishment is seldom displayed elsewhere than within the laboratory of the scientific investigator.

Returning again to a considerably earlier period in the history of primitive man, the discovery of the means of producing and the art of utilizing fire must have demanded abundant employment of observation, comparison, deduction and trial. I have elsewhere endeavored[2] to reconstruct in imagination the train of events which culminated in these discoveries. In the first instance the discovery of fire was probably fortuitous, but the number of factors, friction between the right types of surfaces, the presence of tinder of the requisite inflammability, the assistance of combustion by a current of air, while insufficiently

[2] "The Universe and the Mayonnaise and other Stories for Children." London and New York, John Lane, 1913.

large to preclude a not infrequent inadvertent assemblage of favorable conditions, was nevertheless sufficiently large to render their control at will a scientific problem which, to man at this stage of his development and facilities, must have been one of very formidable dimensions. We only know that it was surmounted, perhaps not once but many times. The laborious individual steps and the flashes of intellectual insight which led up to the conquest are necessarily lost to us forever.

If any of my readers is inclined to think that I place too high a valuation upon the intellectual exertions of primitive man, let him but try, as the author has done, with the powerful assistance of a modern jack-knife and all the inspiration afforded by familiar models, to make a practicable fire-stick or a bow and arrow which shall be something more than a toy. At the end of a few hours or days of endeavor he will have acquired a very enhanced respect for his ancestors.

The development of agriculture in its earliest stages called for foresight and prudence, but not, perhaps, for such extreme exertions of investigative ability as the inventions upon which I have hitherto been dwelling. Directly it passed the first stage of collecting edible plants in a convenient neighborhood, however, the development of agriculture demanded its share of observation, comparison, deduction and trial. The relationship of moisture to the growth of plants would be observed by a comparison of relative growth in different localities or patches of the same locality. In the neighborhood of rivers this would lead to irrigation and that in turn to the acquirement of some of the fundamental notions of hydromechanics. It would be observed, for example, that water would not flow up-hill except under pressure, that a "head" of water was capable of exerting pressure, that the water in two connected vessels tends to reach the same level in each, etc. The transition from a recognition of these principles to the formulation of the erroneous but exceedingly useful doctrine of the incompressibility of fluids required only the incorporation of mathematical conceptions which were destined to be the bye-product of the apparently unrelated enterprises of astronomy and architecture.

The development of architecture is generally traced from the tent of skins and the cabin of logs. Directly more ambitious edifices came to be attempted, however, a knowledge of the strength of materials and the relationship of stress and strain to structure became an imperative prerequisite of success, and by the now familiar process it was acquired. As the constructional details of a large edifice were too numerous to be simultaneously borne in mind, design became a necessary part of architecture, and geometry sprang from design.

The stars must necessarily have riveted the restless curiosity of man from a very early period in his development. Their utility as landmarks and as guides must speedily have impressed themselves upon

migratory people, and this would lead to a recognition of the periodicity of their apparent motions. These periodic changes, beginning with those of the sun and moon (leading to the conception of the day and month), laid the rude foundation of a calendar, the utility of which to the political leaders and organizers of mankind speedily became so evident that the calendar has from the dawn of history been regarded as an important preoccupation of government. From this sprang the early importance of the astrologer in the eyes of the state, more especially as the interpretive fertility of man's imagination had from an early period sought causes for the majestic harmonies of the skies, and these causes, so remote and so all-powerful, were well qualified to arouse the awe and veneration of mankind and an acknowledgment of man's impotence before the mighty forces of the universe and his respect for those whom he believed qualified to interpret the manifestations of this supernal power.

Under what circumstances and by what stages arose the primitive methods of isolating metals from their ores, of mixing them in the requisite proportions to form alloys possessed of properties differing from those of either constituent, and of fashioning the fragments thus obtained into instruments of war and agriculture we can not hope ever to definitely ascertain, but of this we may be absolutely certain, that the intellectual labors and expenditure of patience required to elaborate these crude beginnings of metallurgical science must have far exceeded the labor which, with all the wealth of accumulated experience and organized scientific knowledge we now possess, suffices to accomplish the elaboration of the numerous refinements and improvements of the metallurgical arts which are constantly issuing from our laboratories to-day.

During the ages which witnessed these remarkable developments of human control over nature, parallel developments had inevitably occurred in the juridical and political institutions of mankind. It may however be safely inferred that these developments rarely preceded but were rather the consequnce of the development of man's control over his environment. From their very nature it follows that these institutions are opportunist, and deal with things and men as they find them. For a politician in a pastoral society to frame and enact legislation adapted to an industrial population would be a folly which would speedily and inevitably precipitate disaster. Laws, whether laws of custom, tribal etiquette, or statutory enactment, were necessarily adapted to the people and environment on which they were imposed. Nothing can be clearer then, than that the formative forces which have created civilization have not resided in these institutions of mankind which have merely crystallized preexisting conditions into avowed and recognized forms. The creative forces have resided elsewhere and

their source, whether expressed as the material outcome of science or the spiritual outcome of religion, must be sought in the creative curiosity of man operating through the medium of a discipline of thought which has in every age been essentially identical with the now avowed and self-conscious discipline of thought which is most extensively and successfully employed by the scientific men whom we term to-day investigators and inventors. The ascent of man has therefore not been due, as historians would have us believe, to superhumanly wise statesmen, conquerors or administrators but solely to science and to the anticipations of its fruition which formed the basis of religions.

The increasing complexity of needs and industries now compelled cooperation, the improvement in the machinery of war, backed by the organization and discipline which sprang up in answer to the opportunities this machinery afforded, rendered extensive conquests feasible and the developments of agriculture rendered possible enormous accumulations of population in especially favorable localities. Hence at the dawn of recorded history we find the great river-beds and deltas of the east inhabited by dense populations loosely welded by conquest into inchoate empires.

The close association and interdependence of interests and information which these aggregations of humanity compelled furnished a tremendous stimulus to the development of knowledge and the control of the environment which they inhabited. Vanity inspired monumental architectural undertakings, necessity created intensive agriculture and vast irrigation enterprises, commercial or military necessity created ships out of the canoes and cockle-shells of primitive fishermen, and through the interchange of information and imitation and reapplication of successful devices a comprehensive rearrangement of preexisting knowledge took place, analogous to the modern development of the card index or vertical file from the bound register of inflexible dimensions, a rearrangement which without of necessity adding anything to knowledge, rendered existing knowledge very much more efficient.

During the growth of these great empires a people had arisen in the west, who were but little favored by natural environment but among whom the instinct of curiosity attained the intensity of a passion. Their very intelligence and energy, however, forbade their conquest and fusion into large conglomerates, while the absence of natural conditions favorable to the formation of dense aggregates of population subjected them to a wide dispersal and constant conflict with the forces of nature and with each other. Only the example afforded by contact with more favored and therefore more advanced civilizations was required however to bring about a speedy reversal of the relations of master and pupil in the curricula of civilization. The Greeks, whose gift of inspired curi-

osity has never been surpassed, perhaps indeed never equalled, most happily, by geographical proximity, furnished the connecting channel by which the accumulated knowledge of the east flowed to the receptive peoples of the west. But with their restless temperament and intellectual gifts the Greeks could not be mere passive recipients of facts. Everything that they received from Egypt, from Persia and from Asia Minor was transmitted to the west and to posterity marked with the indelible stamp of Greek genius. Isolated facts garnered from the east were multiplied by Greek investigators and welded into comprehensive generalizations.

For the first time the professional scientist who pursued science for its own sake appears in history. The multitude of isolated medical observations of the ancients were multiplied and interwoven into a system of medical practise by Hippocrates of Cos, and so intense was the enthusiasm and idealism with which he inspired his students that to this day the medical student enters upon the practise of his profession with the avowal upon his lips of the principles of medical practise which were enunciated by this great master. Geometry was applied to science by Archimedes and the fruits were the foundations of hydrostatics and mechanics. Great systematists like Democritus and Aristotle gathered together countless facts of nature and endeavored to weld them into a connected and interpretable whole.

With pupils such as these it is not surprising that the antique wisdom of the east had soon to turn to the west for inspiration. Greek architects were in request from the Ganges to the White Nile and Greek engineers directed the construction of those massive feats of engineering which were the stable foundations of the Roman Empire.

The fall of the Roman Empire, at first seeming the absolute destruction of civilization, simply resulted by steps which are too well known to require description here, in the dispersal of the seeds of knowledge over the continent of Europe. The practical knowledge of the Greeks was safe in the hands of countless artisans and engineers who transmitted it by word and example, enriched by experience and practise, to generations which succeeded them. The more abstract generalizations and inspired literature of the Greeks were kept alive by the sudden awakening into intellectual activity of a people who never before had evinced, and, their task accomplished, have never since displayed capability or desire of assimilating and constructing thought. Not only did the Arabs preserve for us the most perfect fruits of Greek thought, but they contrived a fresh and most significant importation from the east, algebra, the distinctive product of the contemplative rather than the kinetic intellect, a system of thought as truly expressive of the mentality of the peoples of India to whom we owe it as geometry was of the more rugged and virile mentality of the Greek.

Through the Feudal Ages, progressing slowly but inevitably towards the dawn of the renaissance, the seeds sown broadcast by the fallen empire germinated and brought forth fruit. By imperceptible degrees man's mastery over his environment became more complete, the slow sure grasp of science, never again to be relaxed, compelled nature to yield her secrets one by one. The augmenting industrialism and feats of engineering which heralded the renaissance were the fruit of the unregarded effort of countless individuals each of whom added a particle of knowledge to the accumulated store of science.

Practical knowledge was far advanced, but had fallen again into the disconnected condition in which the Greeks at an earlier period had received it from the east. Algebra was an independent branch of human thought, bearing no obvious relation to anything of practical import. The scientific discipline of thought, unconsciously employed by every artisan and engineer, had never been consciously formulated or avowed. The material was there, it awaited only the coming of the man who should weld it together and vitalize it with the inspiration of genius.

The man was found in René Descartes, who, as he tells us,[3] in the seclusion of "a room heated by a stove" wedded algebra to geometry, mathematics to science, and at the same time formulated in words and translated into acts one of the fundamental canons of scientific method, namely *"a plurality of suffrages is no guarantee of truth."*

On that day science attained its majority and assumed self-consciously the burden of its appointed task. The last link was forged in the long chain of human endeavor which stretches from the insatiable aimless curiosity of our well-nigh Simian ancestors to the sublime conceptions of a Newton.

> Of all strong things none is more wonderfully strong than man. He can cross the wintry sea, and year by year compels with his plough the unwearied strength of earth, the oldest of the immortal gods. He seizes for his prey the aery birds and teeming fishes, and with his wit has tamed the mountain-ranging beasts, the long-maned horses and the tireless bull. Language is his, and wind-swift thought and city-founding mind; and he has learnt to shelter him from cold and piercing rain; and has devices to meet every ill, but death alone. Even for desperate sickness he has a cure, and with his boundless skill he moves on, sometimes to evil, but then again to good.[4]

[4] Sophocles, "Antigone."

[3] "Discourse on Method," part II.

THE CONSERVATION OF THE NATIVE FAUNA

By WALTER P. TAYLOR

MUSEUM OF VERTEBRATE ZOOLOGY, UNIVERSITY OF CALIFORNIA

THE ascendancy of man has been accompanied by certain inevitable changes and readjustments in nature. Probably the most conspicuous of these changes is that brought about by the cutting down of forests. Almost as conspicuous, and perhaps even more worldwide in distribution, are those changes resultant upon the destruction of the native fauna, and particularly of birds and mammals. In practically every country of every continent where formerly the "wild flocks and herds held sway," man has crowded out or thoughtlessly destroyed the resident animals until the problem of the preservation of representative faunas is coming to be one of the important concerns both of zoologists and governments in widely separated localities. With this as the background, it now becomes peculiarly desirable to trace the recent history of some of the more important species, limiting ourselves perforce to a few members of one of the great classes in a geographic area of limited extent.

Perhaps there is no more favorable unit in which to carry on our study than that comprised within the boundaries of California. Characterized not only by comparatively great area, but also by climatic features ranging from almost subtropical to boreal, and by a topography of almost infinite variety, it is small wonder that California possesses a mammal list including 369 different species or subspecies, as compared with 80 for Kansas,[1] 94 for Nebraska,[2] 152 for Colorado,[3] and 182 for Texas.[4]

Obviously the species likely to be in greatest danger everywhere are the game species, plus those species against which a public prejudice exists for one reason or another, and those species which, through the fur trade or otherwise, enter into the world's commerce.

Although it must be admitted that much of her inheritance has passed away, there is still plentiful evidence to indicate that California possessed an early fauna of such generous abundance as to justify according her a place among the big game countries of the world.

What are the specific items? Of the smaller fur-bearing species

1 Swenk, "Nebraska Blue Book," 1915, p. 836.

2 The same, pp. 851–855.

3 Cary, U. S. Dept. Agric., Bureau Biol. Surv., N. Amer. Fauna, 33, 1911, pp. 51–211.

4 Bailey, U. S. Dept. Agric., Biol. Surv., N. Amer. Fauna, 25, 1905, pp. 51–216.

there are forty-seven, distributed according to current taxonomic conceptions, as follows: three coyotes, seven gray foxes, four red foxes, one ringtailed cat, four species of raccoon, one marten, one fisher, one wolverine, four weasels, one mink, five spotted and the same number of striped skunks, two badgers, one river otter, the sea otter, four wild cats, and two beavers. This does not take account of any domestic species, nor of the native aplodontias, marmots, squirrels, musk-rats or rabbits, the fur of which doubtless occasionally found place in the early industries of the state.

Beside the smaller species just enumerated, our fauna contained a sea elephant, and is or was characterized by a goodly list of species of more strictly big game mammals, including the pronghorned antelope, two species of bighorned sheep, the same number of black bear, two species of elk, two of mountain lions, five of deer, and six of grizzly bears.

By outlining the status of the more important of these mammals, and by following them in some of the vicissitudes of their contact with man, we can perhaps best gain a conception of what we did have, what we still have, and what the general trend of events promises for the future.

Fur-Bearing Mammals

Concerning the less important fur-bearers there are few comparative data. Evidence gathered over several years from numerous trappers indicates their steady decrease. Even yet the economic value of these for the most part unappreciated members of our fauna is not inconsiderable. In fact, according to one estimate,[5] California's fur-bearing mammals, including only the bears, raccoons, skunks, badgers, river otter, mink, marten, fisher, red foxes and wolverine, at the present time produce an income which makes them worth seven million dollars to the state.

Of the fur-bearing land mammals, the otter and beaver seem to have been the most important. The abandonment of California as a field of work by the Hudson's Bay Company in 1841 is in itself unmistakable testimony regarding the decrease in numbers of these species. So far as can be ascertained at the present time, the otter is represented by comparatively few individuals on the "streams of northern California, south at least to Mendocino County, and through the Sacramento and San Joaquin valleys to the San Joaquin River, Fresno County."[6]

The Beaver

In 1829 McKay, working in the interest of the Hudson's Bay Company, is said to have trapped 4,000 beavers along the reedy shores of

[5] Taylor, *Science*, N. S., March 28, 1913, pp. 485–487.

[6] Grinnell, *Cal. Acad. Sci.*, 4th Ser., 3, 1913, p. 297, and Univ. Calif. Publ. Zool., 12, 1914, pp. 305–310.

San Francisco Bay alone. Dr. T. S. Palmer, in a conversation with the writer, asserted that in the seventies the lowlands of the San Joaquin Valley were a veritable trapper's paradise. In the ark of one trapper, on Old River, about fifteen miles above Webb's Landing, in the spring of 1877, he saw beaver skins piled flat as high as a six foot door. Evidently the beaver has become scarcer and still more scarce as the years have gone by, until it has seemed doubtful whether the species could survive even with the total protection which has for several years been accorded it. It must be admitted that of late the outlook is more hopeful. There is said to be a colony of one hundred and fifty in the Cache Slough district in the Sacramento River, as well as another considerable colony on the San Joaquin River near Mendota; and scattered individuals and colonies have been reported from the Pit, Sacramento, Merced, Tuolumne and Stanislaus rivers. It is probable that a few still occur on the Feather and American rivers, but the exact status of the species on these streams at present is unknown.

The Sea Elephant

We are prone to forget or overlook the intimate relation between the interests of man and the presence of the native animals. An illustration of what is perhaps one of the more unusual of these relationships is furnished by the case of the sea elephant, the abundant oil of which, according to Stephens, was much in demand as an illuminant in the early days in this state previous to the general use of coal oil. The market created by pioneer necessities, coupled with the sluggish temper of the animal, both mental and physical, evidently conspired to work its doom in our waters. Formerly found in some numbers, we must believe, along our southern coast and as far north as Point Reyes, it is gone completely from our shores, being reduced to a handful of survivors on Guadalupe Island off the coast of Lower California.[7]

The Sea Otter

The most aberrant of all living fissipedian carnivores as well as "the most valuable fur-bearing mammal in the world" is the sea otter. These animals were present in abundance off our shores at least until the early part of the nineteenth century. Bryant[8] has called attention to the fact that in the year 1801 no less than sixteen ships, one English and fifteen American, were on the Californian coast engaged in the pursuit of the sea otter. Bancroft, the historian, asserts that 18,000 otter skins were collected that year for the China market by the American vessels alone. In 1812 as many as seven or eight hundred sea otters

[7] See Townsend, *Proc. U. S. Nat. Mus.*, 8, 1885, pp. 90–93; "Pelagic Sealing, Extract from the Fur Seals and Fur Seal Islands of the North Pacific Ocean," Part III, 1899, p. 267; and *Zoologica*, 1, 1912, pp. 172–173.

[8] *Calif. Fish and Game*, 1, 1915, p. 97.

are said to have been killed in San Francisco Bay. These statements may be exaggerated, but they do indicate that the sea otter was an important object of pursuit. In 1785 the price ranged from $1 to $7 per skin.[9] In 1880 the average skin taken off our coast brought $80, while in 1910 the average price paid for sea otter skins in London was said to be $1,703.33. These figures seem to indicate that the demand is inversely proportional to the number of the animals available. For it should be remarked that although the sea otters formerly occurred in suitable localities all the way along our coast, they have completely disappeared from off northern and southern California, although individuals and small companies are still observed in the vicinity of Point Sur, Monterey County, and there is some evidence to indicate that since the passage in 1913 of the law giving them rigorous protection they are increasing slightly.

Deer

The deer is at the present time the most important game mammal in the state, and promises to maintain its preeminence for many years to come. Few species have been able to adapt themselves to the occupation of man as well. But this does not mean that there has not been a decrease in numbers. Hittell,[10] writing of the black-tailed deer, says:

> In 1835, when Dana sailed into the bay of San Francisco, the hills around and the islands in the bay were overrun with them. On a sloping bluff near the Golden Gate, under which his vessel anchored, there were herds of hundreds upon hundreds, which stood still and looked at the ship, until, frightened by the noises made for the purpose of seeing their graceful movements, they bounded off.

Traffic in deer hides was carried forward until a comparatively late date. In 1842 deer and elk hides brought only from fifty cents to a dollar apiece in San Francisco. The considerable traffic which was carried on even at these low prices bears unmistakable testimony to the great numbers of the species concerned. Evidently deer were numerous, not only in the mountains, but on the plains, where now the sight of one would awaken the most extraordinary interest.[11]

Nominally there are five subspecies of deer within the state, two of black-tailed, three of mule deer.

The Columbia black-tail is still found abundantly in the northern coast district south to the Golden Gate, its range embracing Mount Shasta to the north and east, and taking in all the coast ranges east to the Sacramento Valley.

In the coast belt south of San Francisco, at least to Monterey and San Benito counties, its place is taken by the southern black-tail.

[9] Bryant, *Calif. Fish and Game*, 1, 1915, p. 97. Probably none of the skins sold in London in 1910 came from Californian waters.

[10] "History of California," 2, 1898, p. 562.

[11] Newberry, Pac. R. R. Reports, 6, 1857, Zoology, p. 66; and Bosqui, "Memoirs," 1904, pp. 62, 66.

The true mule deer is the form characteristic of the Sierra Nevada and the mountains of the extreme northeastern portion of the state in Modoc county. The mountains in southern California west of the desert proper are occupied by a small subspecies called the California mule deer, the range of which extends north at least to San Luis Obispo county and the Tehachapi mountains.

The burro deer (*Odocoileus hemionus eremicus*) formerly occurred on the deserts of the southwestern portion of the state bordering on the Colorado river. Members of the expedition from the Museum of Vertebrate Zoology to this region in 1910 were unable to find so much as a trace of the presence of the species, although they were told of its occurrence in numbers many years before, ". . . when they were to be found both in the river bottom and back through certain desert ranges, where there are springs which the deer could visit regularly for water."[12] No one in the vicinity had seen a deer within four years. As the record runs the date of the extirpation of the burro deer in California may be set down as approximately 1905 or 1906.

I may not leave the account of the deer without remarking the persistent rumors of the occurrence in the Modoc region of extreme northeastern California of white-tailed deer (*Odocoileus virginianus macrourus*); but so far no definite evidence in the shape of specimens has come to light.

It is quite certain that not only have the deer decreased markedly since the beginning of the nineteenth century but also that they are fewer in numbers than they were, say, ten, or twenty years ago. In some sections, notably in southern California, they are losing ground rapidly; in others, as in the Trinity-Siskiyou region of northern California, they are reported to be holding their own and even in certain localities to be increasing. It is not improbable that the number of deer killed by hunters under modern conditions, large as it is, aggregates a much smaller total than in former days, when individual bands of hide and market hunters slaughtered deer by hundreds and even thousands in a season.

Incidentally, testimony to the size of California and to her comparative supremacy as a game state even yet is given by the fact that in few states are more deer killed annually than are killed within her borders.

Elk

Our largest ungulate is the elk or wapiti, of which we have two species; one, perhaps known most commonly as the Roosevelt elk (*Cervus roosevelti*) formerly found numerously in the humid north coast belt south at least to the Golden Gate and east to Mount Shasta; the other, the valley elk (*Cervus nannodes*) found predominantly in the San Joa

[12] Grinnell, Univ. Calif. Publ. Zool., 12, 1914, p. 219.

quin Valley and low-lying regions tributary thereto. Dr. Newberry,[13] writing of the elk in early days, says:

> West of the Rocky mountains, it was formerly most abundant in the valleys of California, where it is still far from rare. In the rich pasture lands of the San Joaquin and Sacramento, the old residents tell us, it formerly was to be seen in immense droves, and with the antelope, the black-tailed deer, the wild cattle, and mustangs, covered those plains with herds rivalling those of the bison east of the mountains, or of the antelope in south Africa.

Bosqui[14] while making a journey from Stockton to Mariposa in December, 1850, records seeing "bands of elk, deer, and antelope in such numbers that they actually darkened the plains for miles, and looked in the distance like great herds of cattle."

Hittell[15] includes as one item in a list of exports from San Francisco in 1842 three thousand elk and deer skins at prices ranging from fifty cents to a dollar. Robinson[16] asserts that the American elk, occurring on the northern side of San Francisco Bay, was then hunted for its tallow, which was preferred to that taken from bullocks.

At the present time the Roosevelt elk is making a last stand in the extreme northwestern portion of the state in the counties of Humboldt and Del Norte; while the valley elk is reduced to a herd in the tule lands of the southern San Joaquin Valley estimated to contain four or five hundred head. In 1905 the United States Department of Agriculture succeeded in transporting twenty-six of these elk to the Sequoia National Park in Tulare County, where the herd has now increased to about fifty head. About a year ago the California Academy of Sciences distributed fifty-four of the valley elk to seven parks and reservations in different parts of the state, where conditions were most favorable for their survival.

That the elk has taken a strong hold upon the interest and imagination of the people of California is shown by the fact that the killing of an elk within the state is made a felony, which is the severest penalty imposed for the violation of any game law within the commonwealth.

Mountain Sheep

The description of the mountain sheep of the high Sierra by Grinnell[17] is one of the most interesting of recent developments in California mammalogy. The pioneer zoological investigators[18] connected with the Pacific railroad surveying parties all report mountain sheep on Mt. Shasta. Newberry's account says:

13 Pac. R. R. Reports, 6, 1857, Zoology, p. 66.

14 Quoted by Evermann, *Calif. Fish and Game*, 1, 1915, p. 86.

15 "History of California," 1898, 2, p. 479.

16 "Life in California," 1846, p. 61.

17 Univ. Calif. Publ. Zool., 10, 1912, pp. 143–153.

18 Newberry, Pac. R. R. Reports, 6, 1857, Zoology, p. 72; Kennerly, same, 10, 1859, p. 72; and Suckley and Gibbes, same, 12, p. 137.

On the slopes and shoulders of Mount Shasta the *Ovis montana* exists in large numbers; so much so that one spur of the mountain has been named "Sheep Rock" and there hunters are always sure of finding them.

The bighorn was referred to also as being habitually present in the vicinity of Rhett and Wright Lakes, eastward from Mount Shasta. The Modoc Expedition from the Museum of Vertebrate Zoology, 1910, found evidence of their former presence in the Warner Mountains of extreme northeastern California. Stephens[19] asserts that bighorns were ". . . formerly found in parts of the Sierra Nevada and on Mount Shasta, but they are apparently now exterminated in those mountains."

In October, 1911, in a section of the Sierra Nevada which is a portion of one of the wildest and most scenic regions in the world, there were secured the specimens on which the description of the form was based. It is asserted by Ober,[20] deputy fish and game commissioner for the district, that there are three bands of the Sierran bighorn ranging over a comparatively restricted tract of jagged and precipitous country on the face of the Sierran fault block. Grinnell[21] has set the northern and southern limits of range of the species as being respectively Mono County and Mount Whitney. A recent definite record of bighorns on the west slope of the Sierras is for the north spur of Mount Silliman, altitude 10,600 feet, within the Sequoia National Park, where sheep were seen August 19, 1910.[22] It is quite likely that the former range of the species included Mount Shasta and the Modoc region.

The Nelson bighorn, a smaller, shorter-haired species than its Sierran relative, is typical of the desert ranges of southeastern California, from the Inyo region south at least to the Mexican line.[23] Formerly it is said to have occurred northwest through the Tejon region to the Caliente Hills, San Luis Obispo County, and there are reports of its persistence still in scattered localities in this general district. At present the desert sheep is apparently increasing in some sections of its range, notably the desert ranges in Inyo County,[24] and stationary or decreasing in others, as in the desert portions of the more southerly counties, San Bernardino, Riverside and Imperial.[25] There are, fortunately, some large bands which promise well, and which at least indicate that there is no cause for concern over the immediate future of the species within the state.

19 "California Mammals," 1906, p. 58.

20 23d Bien. Rpt., Calif. Fish and Game Com., 1914, p. 125.

21 *Proc. Calif. Acad. Sci.*, 4th Ser., 3, 1913, p. 369.

22 [Fry], "Sequoia and Gen. Grant Nat. Parks," Gen. Inf., Dept. Int., 1915, p. 22.

23 Grinnell, *Proc. Calif. Acad. Sci.*, 4th Ser., 3, 1913, p. 369.

24 Ober, 23d Bien. Rpt., Calif. Fish and Game Com., 1914, pp. 123–124.

25 See Stephens, same, pp. 128–130.

Pronghorned Antelope

Of the pronghorn (*Antilocapra americana*) referred to by Chalmers Mitchell[26] as one of the most isolated and interesting of living creatures, formerly represented by herds of thousands of individuals found practically everywhere on Californian plains, we have only scattering bands remaining. There are still a few in the Modoc region of northeastern California, on the arid western side of the San Joaquin Valley, in that part of the Mohave Desert known as Antelope Valley, and possibly in scattered localities in the extreme southern part of the state. This is the animal which was only a few years ago one of the most conspicuous features of the Californian plains and deserts, as witness the following from Newberry:

> Though found in nearly all parts of the territory of the United States west of the Mississippi, it is probably most numerous in the valley of the San Joaquin, California. There it is found in herds literally of thousands; and though much reduced in numbers by the war which is incessantly and remorselessly waged upon it, it is still so common that its flesh is cheaper and more abundant in the markets of the Californian cities than that of any other animal.[27]

It is not improbable that the antelope's former habitat extended nearly or quite to tidewater. Dr. Colbert A. Canfield of Monterey, who seems to have been a close and careful observer, wrote to Professor Baird in 1858 as follows:

> In your report you say nothing of the existence of the antelope on this side of the Sierra Nevada; but I can assure you that they abound everywhere in all the plains and valleys of the western slope, down to the Pacific Ocean.[28]

A. Robinson in his "Life in California"[29] writes of the San Francisco bay region:

> On the northern side of the bay are found the American elk and antelope, and great quantities of deer. . . .

J. Ross Browne, writing in 1864, says with reference to country traversed by him:

> A large portion of the country bordering on the Salinas river, as far south as the Mission of Soledad, has been cut up into small ranches and farms; and thriving settlements and extensive fields of grain are now to be seen where formerly ranged wild bands of cattle, mustang, and innumerable herds of antelope.''[30]

The pronghorn was apparently sustaining about all the competition it could withstand before the advent of the white man. Since his coming it has been on the downgrade. Apparently his best efforts will be necessary to preserve its life.

[26] *Science*, N. S., Sept. 20, 1912, p. 357.
[27] Pac. R. R. Reports, 6, 1857, Zoology, p. 71.
[28] *Proc. Zool. Soc. London*, 1866, p. 110.
[29] New York, Wiley and Putnam, 1846, p. 61.
[30] ''Crusoe's Island,'' New York, Harper's, p. 174.

The Black Bear

Our biggest living carnivore is the black bear. One subspecies is found in the Transition and Boreal zones of the coast mountains north of San Francisco Bay, while the other, the exact status of which remains to be elucidated, occupies the Sierra Nevada south to the vicinity of the Tehachapi Mountains.[31] Apparently the black bear has never been found either in the coast district south of San Francisco or in southern California.

Although constant persecution has resulted in considerable reduction in its numbers, the black bear has proved a much more resilient and adaptable species than the grizzly; and there are good grounds for the hope that with fair treatment it may be counted on as an important big game and fur-producing species for many years to come.

The Grizzly Bear

Beyond all question the group of her grizzly bears was the most vividly impressive portion of the native fauna of California. No less than six distinct forms are now recognized by Dr. C. Hart Merriam[32] as belonging to the fauna of California alone.

Let me briefly list them: *Ursus klamathensis* is described from Klamath river; *Ursus colusus* is from the Sacramento Valley, the type skull coming, in all probability, from somewhere on the river between Colusa and Sacramento; the huge *Ursus californicus,* known by name longer than any of the others, is restricted to the Monterey region; from the historic old Fort Tejon, in the Tehachapi Mountains, comes *Ursus californicus tularensis,* also found in certain ranges of southern California; the smallest of them all, *Ursus henshawi,* comes from the southern Sierra Nevada; while the Trabuco Mountain region of southern California was the home of the gigantic *Ursus magister,* the ". . . largest of known grizzlies, considerably larger than *Ursus californicus* of the Monterey region, and even than *Ursus horribilis,* the great buffalo-killing grizzly of the plains (only equalled by the largest *alexandræ* of Kenai peninsula)."[33]

Bryant[34] records the fact that Bidwell, in Rogers's "History of Colusa County," states that when the county was first settled it was not uncommon to see thirty or forty grizzly bears in one day.

Hittell submits the following:

> In early times grizzly bears were very plentiful all over the country and did great damage to the cattle and gardens of the first settlers. In 1799 the troops of Purisima made a regular campaign against the bears of that region.

[31] Grinnell, *Proc. Cal. Acad. Sci.*, 4th Ser., 3, 1913, p. 284; and C. H. Merriam, conversation.

[32] *Proc. Biol. Soc. Wash.*, 27, 1914, pp. 173–196.

[33] Merriam, *Proc. Biol. Soc. Wash.*, 27, 1914, p. 189.

[34] *Calif. Fish and Game*, 1, 1915, p. 96.

In July, 1801, Raymundo Carrillo wrote from Monterey that the vaqueros in that neighborhood had within the year killed thirty-eight bears, but that the depredations by others continued unabated; and he proposed an ambuscade by the troops at a certain place where the carcasses of a few old mares should be exposed.[35]

Newberry writing in 1857 asserts concerning the grizzlies:

They are rather unpleasantly abundant in many parts of the Coast Range, and Sierra Nevada, in California, where large numbers are annually killed by the hunters, and where not a few of the hunters are annually killed by the bears.[36]

The general vividness with which the grizzly impressed himself upon the pioneers as the original native son is indicated by the fact that he was painted, by common consent, as the totem of the commonwealth, on the first flag of the "California Republic."

For several years strenuous efforts have been made to obtain authentic records of living grizzlies in California, so far without success. It seems quite safe to state that each and every one of the six species is now completely extirpated from our fauna.

For the outline of the former range of these bears we must look forward to the publication of the results of Dr. Merriam's exhaustive researches. The fragmentary material now available will not permit of any detailed distributional statements. The actual dates of extermination of the various species are uncertain. The skull from the southern Sierra Nevada, which became the type of *Ursus henshawi,* was collected by Dr. J. T. Rothrock and H. W. Henshaw in 1875. Two specimens, skins only, from the Tehachapi region, and supposedly referable to *Ursus californicus tularensis,* are in the Museum of Vertebrate Zoology and were collected in the Tejon (or San Emigdio) Mountains, between San Emigdio Ranch and Old Fort Tejon, between 1893 and 1896. The type of the huge *Ursus magister* of southern California was shot in the Santa Ana Mountains in August, 1900 or 1901, and there are no known records subsequent to this date.

The Zoologist and the Preservation of the Native Fauna

That California's early endowment of wild life was generous indeed seems clearly to be indicated by this brief survey; and that there has been a steady decrease in numbers of practically all the game and fur-bearing mammals seems to be equally clear. We now count, among mammals alone, at least eight species which are totally extirpated from our fauna.

Nor is California a special offender. The same story of the dwindling numbers of the native animals is repeated in nearly every state of the Union; and similar stories are told in Europe, Asia, Africa, South America and Australia.

[35] "History of California," 2, 1898, pp. 560–561.

[36] Pac. R. R. Reports, 6, Zoology, p. 47.

There are few people in these days who deny that when the mountains are spoiled of their forests; when conspicuous and interesting species of game or bird life are destroyed; when any of the natural resources of the people are wasted, then progress is impeded, constructive works retarded, and the conditions of existence rendered more severe.

Fundamental to conservation is scientific research, of course; admittedly our investigations have not penetrated very deeply into the unknown, and this first phase of our work is prerequisite to every other phase. It will doubtless be admitted, however, that we can not possibly postpone action until all points in all problems become clear. This being the case it is due the commonwealth that all available information be brought to bear when legislative action is contemplated; and it is evident that the only citizens who possess any considerable body of information pertinent to the biological side of the problem of conservation are the professional biologists.

It is, fortunately for all concerned, coming to be realized in ever-increasing degree, that in a democracy, the zoological representative of the people, if I may so speak, should maintain cordial and sympathetic relations with those from whom his support is derived and whom he is endeavoring to serve, and that it is only fair that he freely and generously assume a place of leadership in the campaign for the preservation of the native fauna. Indeed, is it not true that unless the zoologist does take pains to get the word to the people at critical times, upon him must inevitably fall a share of the blame for ignorant and destructive popular action, legislative and otherwise?

THE PROGRESS OF SCIENCE

THE CONTROL OF EPIDEMIC DISEASES AND THE CAUSES OF DEATH

The only redeeming feature of the terrible epidemic of infantile paralysis which began in Brooklyn and has spread as far as Philadelphia and Boston, is the attention which it has directed to the control of communicable disease. It may be that the attitude of the public and of certain health boards has been somewhat hysterical, but as a matter of fact it has only been so in certain directions. Thus less than three per cent. of the cases occur in those over ten years of age, and except in so far as they may be carriers of the disease the risk is so small as scarcely to warrant any quarantine or the closing of a university such as Princeton. It is, however, almost impossible to overestimate the importance of using even drastic measures to suppress epidemics. What has been accomplished with cholera, the plague and small-pox can be done in the case of other diseases.

There are here reproduced several diagrams from the United States Census Reports and the Report of the English Registrar General which show the relative death-rates of different countries and the death-rates from different diseases. It is an extraordinary fact that three times as many people should die in Chile as in New Zealand, twice as many in Hungary as in Sweden. These differences also represent the progress made by the more advanced nations. The death-rate in England, for example, has in the course of fifty years been reduced from 22 to 13 per thousand. People live about twice as long as they did a century ago and about four times as long as they did in the middle ages.

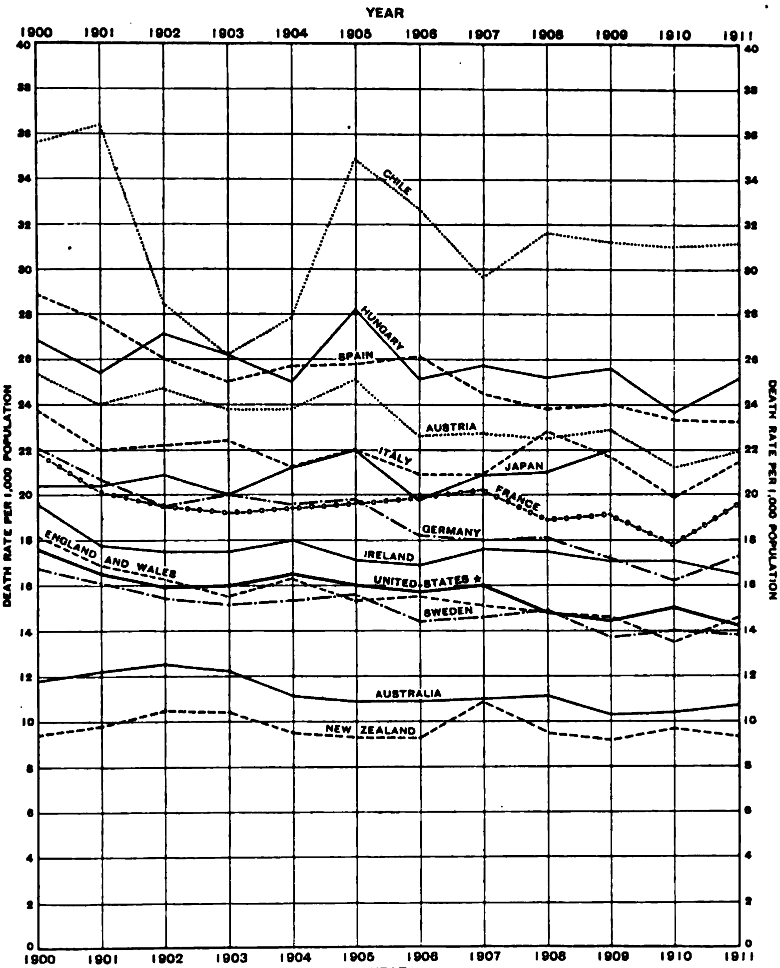
The curves for the principal causes of death in the United States show great changes even in the course of a period so short as twelve years. The most satisfactory aspect of these curves is the decrease in tuberculosis, typhoid and diphtheria, due in the main to three different methods of control, the first to more hygienic conditions of living, the second to suppression of the sources of the epidemic, the last, in part at least, to the antitoxin treatment. There are greater variations in pneumonia and infantile diarrhea, they being influenced by seasonal variations, but on the whole a satisfactory decrease is indicated.

The most unsatisfactory curves are those for the three children's diseases—measles, scarlet fever and whooping cough. They are curiously equal in their incidence and have remained almost constant in their fatality for twelve years. They are far more dangerous than infantile paralysis has hitherto been; they should be regarded with the same dread and their suppression should be undertaken with the same vigor. This is especially indicated by the English figures, where the deaths from these diseases, especially scarlet fever, have greatly decreased. Fifty years ago the annual death-rate from scarlet fever was over 2,600 per million children and this has now been reduced to 250. It is a curious fact that diphtheria since the use of the antitoxin treatment has decreased at only about the same rate as the other diseases, and that it is now as large a cause of death as fifty years ago, while deaths from scarlet fever have been reduced to one tenth.

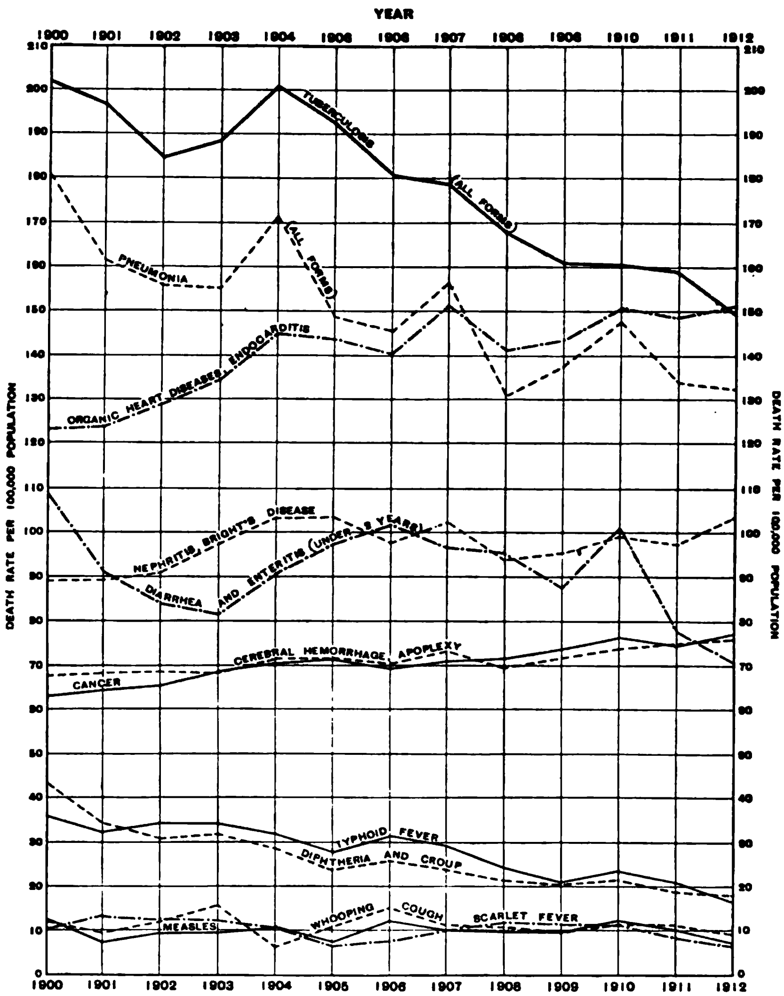
The increase of the organic diseases of later life is marked. Thus the most striking feature in the American statistics is the crossing of the curves for the two most fatal diseases, tuberculosis and heart disease. In 1900 the death rate from the former was 202 per hun-

dred thousand, from the latter 122, but in 1912 the rate for heart disease had become higher than for tuberculosis. An increase is also evident in Bright's disease, apoplexy and cancer. The increase of these diseases has attracted public attention, and has been adduced as evidence of the disastrous pressure of the conditions of modern life in cities and the like. As a matter of fact, an increase in the deaths caused by these diseases may be regarded as propitious. People must die, and if we suppress epidemics and the diseases of infancy and youth death must sooner or later occur through some organic failure.

The fact that the death rate between forty and sixty has remained about stationary in recent decades, while the rate for earlier ages has so greatly decreased, is another matter. This has been interpreted to mean that improvements in hygiene and medicine have been offset by bad conditions of living, the use of alcohol and other drugs, the overpressure of business, the pursuit



GENERAL DEATH RATES OF THE UNITED STATES (REGISTRATION AREA) AND CERTAIN FOREIGN COUNTRIES: 1900–1911.

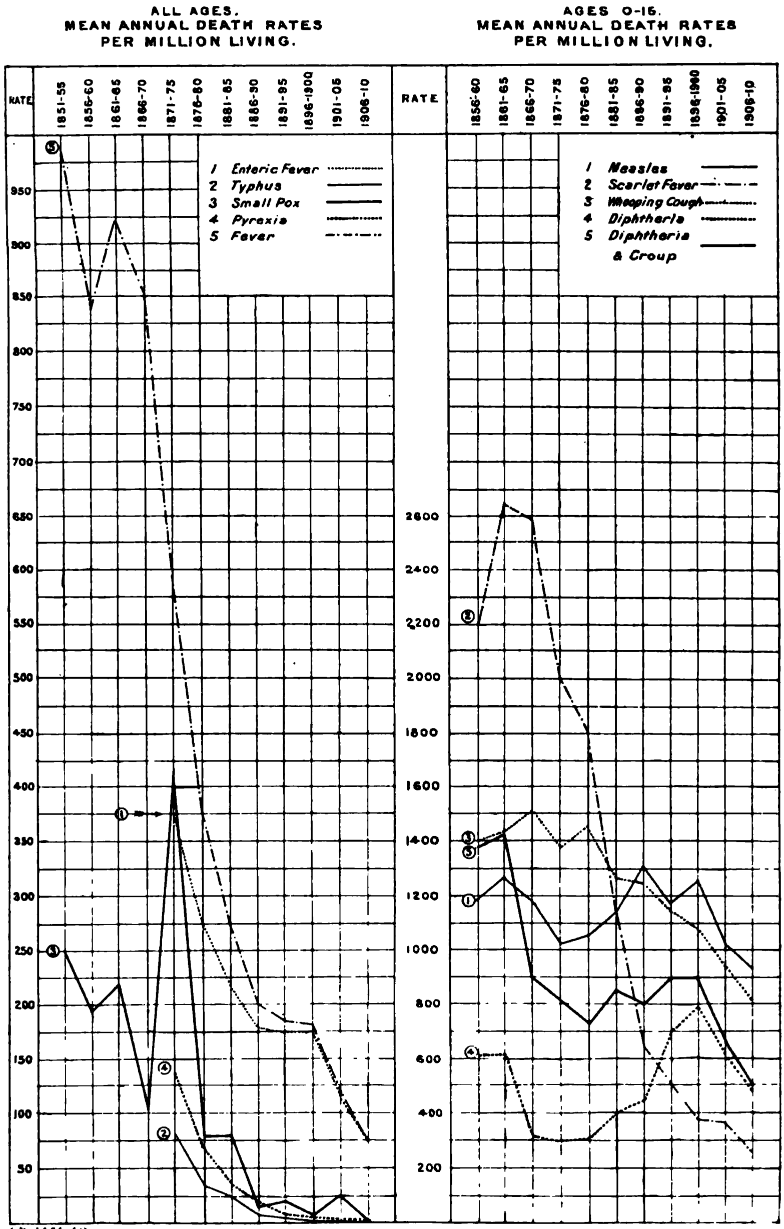


Death Rates from Important Causes of Death in the Registration Area of the United States: 1900–1912.

of pleasure and the like. But another explanation may be urged. If we preserve the lives of hundreds of thousands of infants who can not be properly nursed by their mothers and of hundreds of thousands of young people of inferior constitution who would previously have succumbed to tuberculosis, we have in the population between forty and sixty a large proportion of people less vigorous than those who would have survived harsher conditions. It is not surprising if they have a higher mortality.

WILLIAM RAMSAY AND RAPHAEL MELDOLA

The richness of England in men of scientific distinction is shown by the fact that almost every month it is necessary to record the deaths of those who have contributed in important measure to the advancement of science. It may be feared that the even more

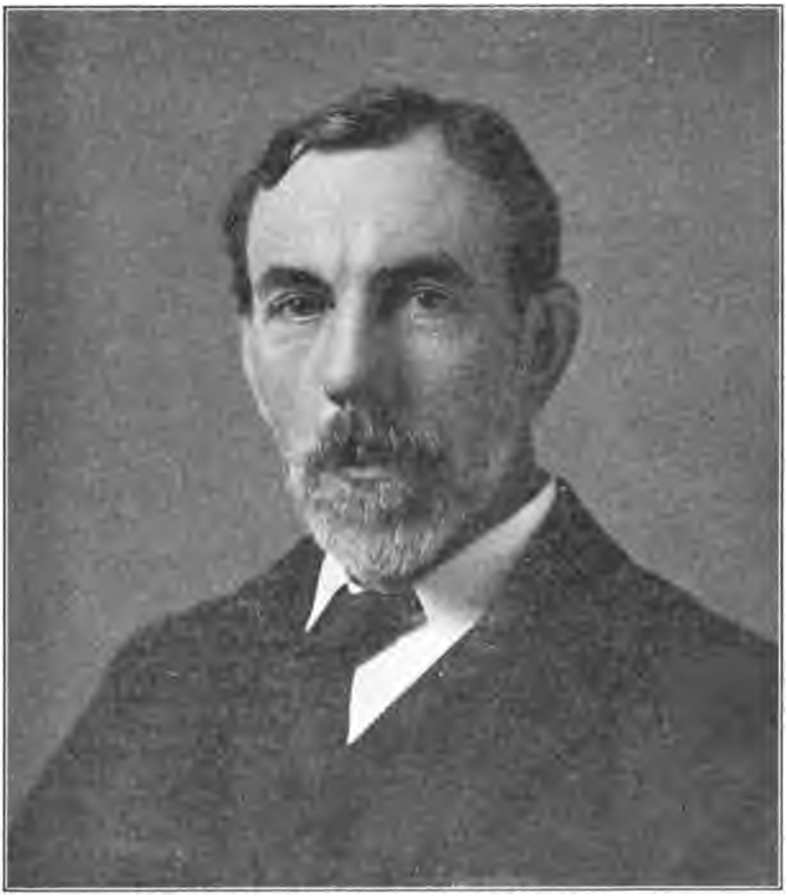


Mortality from Epidemic Diseases in England and Wales by Five Year Periods to 1910.

RAPHAEL MELDOLA.

numerous names of young men of promise in the scientific career who die on the battlefield and in the hospital will leave fewer men of eminence in the next generation. The equal sacrifices, we venture to say equally wanton sacrifices, in Germany, in France, in Russia and in Italy, place great responsibility on us in America to provide in the coming years the research work which is essential to the welfare and the progress of the world. We should be warned not only to save our young men of ability from futile death, but also to give them the opportunity to do the work for which they are fit.

In the death of Sir William Ramsay and the earlier death of Professor Raphael Meldola, England has lost two chemists of world-wide reputation and of striking personality. There are not many contemporary men of science so well known as Ramsay. His earlier researches on organic chemistry, on the molecular weights of liquids and on vapor density and pressure are known to chemists, but it was the discovery, in conjunction with Lord Rayleigh, of argon, announced at the Oxford meeting of the British Association in 1894, which first attracted universal attention. However honors should be divided in the case of argon, Ramsay proceeded himself to the discovery in the uranium



WILLIAM RAMSAY.

minerals of helium, previously known only in the spectrum of the sun's chromosphere. The use of liquid air led to the discovery of three other elements of the same type, neon, krypton and zenon. Ramsay not only discovered the group of inert gases, but also described their monatomic character and their position among the elements.

Two years after the announcement of the discovery of argon, and at nearly the same time as the discovery of helium by Ramsay, Röntgen discovered the X-rays and Becquerel the rays of uranium, followed by the discovery of radium by the Curies. In the three great nations at the same time advances were independently made which gave a new direction to modern physics. To Ramsay belongs the remarkable triumph of having united the work on the inert gases and on radium by demonstrating the genesis of helium from radium. His further transformation of the elements has not been confirmed. Ostwald, who wrote in 1912 a biographical sketch of Ramsay for *Nature,* finds him an apt example of the "romantic type," which he has contrasted with the classical type. The investigator of the romantic type makes errors as well as striking discoveries and proselytes.

Ramsay's grandfather was president of what is said to have been the first

chemical society, his uncle was director to the British Geological Survey. Meldola was descended from a distinguished line of Spanish rabbis. If his grandfather had not moved to England, Meldola would have been more likely to have been a Jewish theologian than a chemist. Both Ramsay and Meldola are members of the "notable families" recorded by Galton as contributing fellows to the Royal Society. We have thus inherited ability in both cases, in the former displayed in a constant direction, in the latter diverted by the environment to a different track. In this connection it is worth noting that Meldola's performance was unusually versatile, as is indicated by the fact that he was president, on the one hand, of the British Chemical Society and the Society of Chemical Industry and, on the other hand, of the British Entomological Society and the Essex Field Club. His first papers were on mimicry and protective coloration in insects and he translated Weismann's "Theory of Descent" into English. He was for thirty years professor of chemistry in the Finsbury Technical College and conducted important researches there on the chemistry of coloring matters.

The writer of this note did not have the privilege of personal acquaintance with Meldola, but he is said to have been, like Ramsay, a man of sympathetic personality, exerting great influence on his students, active in all measures for the improvement of education and for the promotion of science.

SCIENTIFIC ITEMS

WE record with regret the death of Josiah Royce, the distinguished student of philosophy, professor at Harvard University; of Seth Low, formerly president of Columbia University; of Thomas Gregor Brodie, professor of physiology in the University of Toronto; of Sir William Henry Power, F.R.S., known for his contributions to sanitation and public health; and of Johannes Ranke, professor of anthropology at Munich.

SIR T. CLIFFORD ALLBUTT has been elected president of the British Medical Association. A message of congratulation was at the time sent to him on the attainment of his eightieth birthday which occurred on July 20.—Professor C. F. Marvin, chief of the Weather Bureau, and Dr. L. O. Howard, chief of the Bureau of Entomology, have been appointed by the secretary of agriculture to represent the U. S. Department of Agriculture on the Council of Research which is being organized by the National Academy of Sciences.

ON the initiative of the Royal Society a Board of Scientific Societies has been established in Great Britain to promote the cooperation of those interested in pure or applied science; to supply a means by which the scientific opinion of the country may, on matters relating to science, industry and education, find effective expression; to take such action as may be necessary to promote the application of science to industries and to the service of the nation; and to discuss scientific questions in which international cooperation seems advisable. The board at present consists of representatives of twenty-seven scientific and technical societies. An executive committee has been appointed, consisting of Sir Joseph Thomson, president of the Royal Society, chairman; Dr. Dugald Clerk, F.R.S., Sir Robert Hadfield, F.R.S., Mr. A. D. Hall, F.R.S., Professor Herbert Jackson, honorary secretary, Sir Alfred Keogh, K.C.B., Sir Ray Lankester, K.C.B., F.R.S., Professor A. Schuster, secretary of the Royal Society, Sir John Snell, Professor E. H. Starling, F.R.S., Lord Sydenham, F.R.S. and Mr. R. Threlfall, F.R.S.

Vol. 3, No. 5 NOVEMBER, 1916

THE SCIENTIFIC MONTHLY

EDITED BY J. McKEEN CATTELL

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THE SCIENCE PRESS

LANCASTER, PA. GARRISON, N. Y.

NEW YORK: Sub-Station 84

Single Number, 30 Cents Yearly Subscription, $3.00

THE SCIENTIFIC MONTHLY

NOVEMBER, 1916

EXPLOSION CRATERS

By N. H. DARTON

U. S. GEOLOGICAL SURVEY[1]

ALTHOUGH most great craters are on top of volcanic peaks, a few big holes of volcanic origin are on plains and not connected with lava outflows. These are rimmed by a ridge of fragmental material evidently blown out of the hole, so that they are clearly the results of an explosion. One crater of this character, however, Crater Mound (formerly Coon Butte) in Arizona, is believed by some observers to have been caused by impact of a meteor. As there is no direct evidence as to the origin of this great hole and its rim of fragmental ejecta, it may be interesting to present for comparison facts regarding some craters which are closely similar in all essential respects.

Among long-known holes ascribed to volcanic explosion and not connected with lava outbursts are the "maars" in the Rhine valley and the craters of Eiffel, Auverne, Montecchio, Albani, Nemi, Astromi, Faifa, etc., of Nassibe, in Madagascar and at Lonar, India. The latter, as described by Dr. Blandford, is a hole about a mile in diameter, 300 to 400 feet deep, in a great lava plain. Except on the north and northeast sides, there is a rim 40 to 100 feet high composed of loose blocks of basalt similar to the rocks on the sides of the hole. The latter are bent up very slightly. As to the competency of volcanic explosion to cause a crater, many illustrations have been observed, notably in the great Bandai-San eruption[2] in Japan in 1888, which made a vast crater in a mountain where there had been no activity for many centuries. There was no lava effusion connected with this outburst. The eruption of Krakatoa in 1883 is another impressive instance.

In the course of the present European war many a huge "crater" or "entonnoir" has resulted from the explosion of "mines" intended to destroy fortifications or dislodge troops, and it is interesting to have an example of this kind to compare with some natural craters. One

[1] Published by permission of the Director.

[2] "The Eruption of Bandai-San," Seis. Soc. Japan, Vol. 12, pp. 139-222, 1890.

large "entonnoir" on the Franco-German line of struggle is shown on Page 429. Judging from some details of remains of passageways shown in the foreground, its diameter is about 150 feet and depth 50 feet. It was produced by the explosion of several tons of some powerful explosive placed in a chamber at the end of a long tunnel 50 to 60 feet below the surface. The end of the tunnel next the chamber was securely blocked before exploding the mine in order to have the utmost

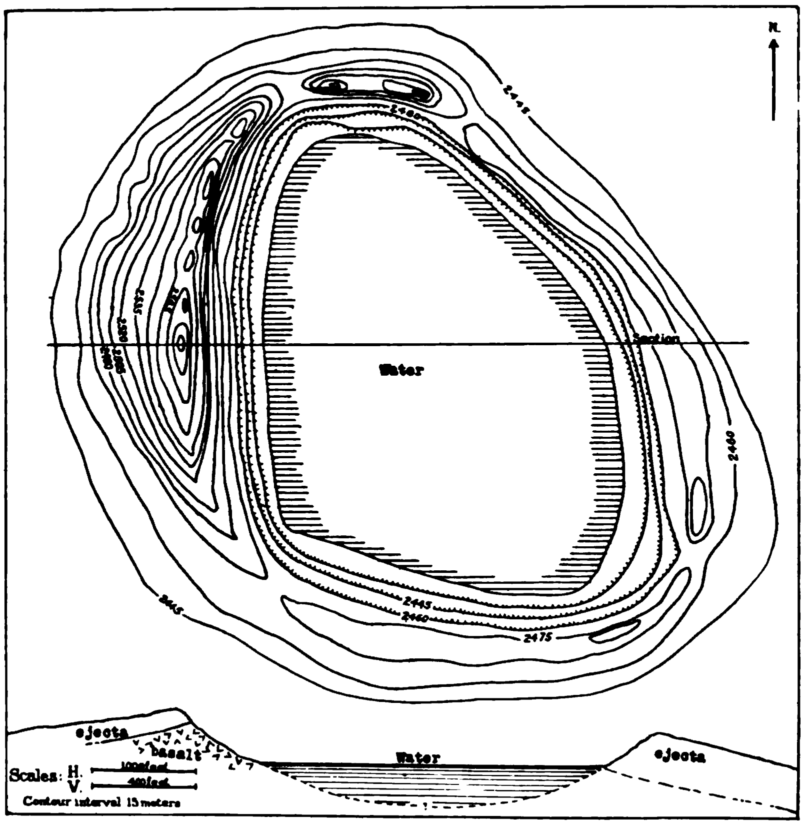

FIG. 1. CONTOUR MAP AND CROSS SECTION OF THE CRATER OF ALCHICHICA IN PUEBLA, MEXICO, AFTER ORDONEZ.

effect of upheaval. The material apparently is compact earth and probably the uplifted material was torn out without much upbending of the sides from which it is detached.

Several years ago Ordoñez described some remarkable craters in Mexico which afford some very interesting facts for comparison. One group is on the plateau near Orizaba Peak in Puebla; the other group is in Valle Santiago. Ordoñez regards them as the result of explosions marking the last phase of volcanic activity in the region. The cause was igneous action at no great depth and the locus of explosion was determined by some superficial influence.

The craters of the Puebla[3] region are in two principal groups. One group of four is in the vicinity of the Hacienda and Sierra of Techachalco, about 25 miles north-northwest of Orizaba Peak and not far southwest of Limon Station on the Interoceanic Railroad. The other group is near Alxoxuca, a small settlement eighteen miles northwest of Orizaba Peak. The configuration and structure of two of the principal members of the first group are shown in Figs. 1 and 2, copied

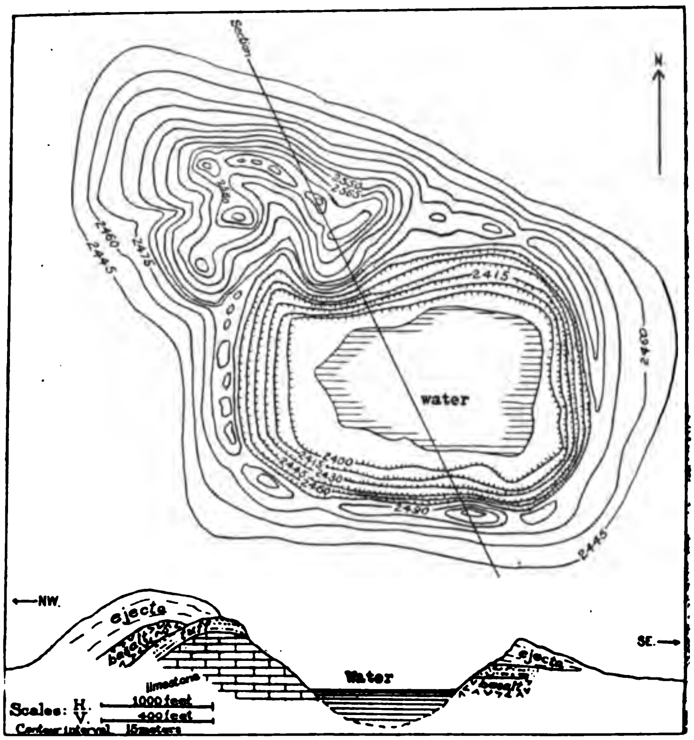

FIG. 2. CONTOUR MAP AND CROSS SECTION OF THE CRATER OF ATEXCAQUI IN PUEBLA, MEXICO, AFTER ORDONEZ.

from Ordoñez's memoir. The largest crater, known as Alchichica, is circular, contains a large shallow lake, and has a diameter of slightly more than a mile. The water level is about 50 feet below the surrounding plain. On the east and south sides the encircling ridge is low, but on the west it rises 325 feet. The inner slopes are steep, the outer ones more gradual. Both walls consist of ash, lapilli and pumice, evidently ejected from the crater, but on the west side these are seen to lie on a mound of basalt of some old flow. Fragments of basalt and of slates, limestones and other materials are included in the mass of

[3] "Los Xalapazcos del Estado de Puebla," Inst. Geol. de Mexico, Parergones, Vol. 1, No. 9, 1905.

ejecta constituting the encircling ridge. There is no evidence of disturbance of the beds.

Atexcaqui, six miles southwest of Alchichica, has an elliptical crater about three fifths of a mile wide from east to west and two fifths of a mile wide from north to south. Some of its features are shown in Fig. 2. The surface of the lake occupying the crater is about 90 feet below the adjoining plain. The encircling ridge is from 200 to 250 feet above the lake, but on the northwest side its height increases to about 600 feet on account of the presence of a mound of horizontal Cretaceous strata on which the ejecta is piled. On the other sides are low walls of basalt, capped by nearly horizontal beds of yellow, andesitic tuff which constitutes the surface of the adjoining plains. The material ejected from the hole and constituting the encircling ridge is piled up on this tuff to a thickness of 40 to 60 feet. The inner slopes of the crater are steep at most places. The ejecta of the encircling ridge is in irregular sheets sloping outward at a low angle. The principal materials are those which underlie the plain: ash, cinders, tuff, and numerous fragments of the basalt. There is also a small proportion of limestone, granite, diorite and andesite, such as probably underlie the locality at considerable depth. The limestone is of the same sort as that which constitutes the hill on the northwest side of the crater. The explosion has blown a round hole through the basalt, limestone and overlying tuff, but has not disturbed the remaining edges. The volume of ejected material is not estimated, but it must be great and apparently sufficient to fill the hole.

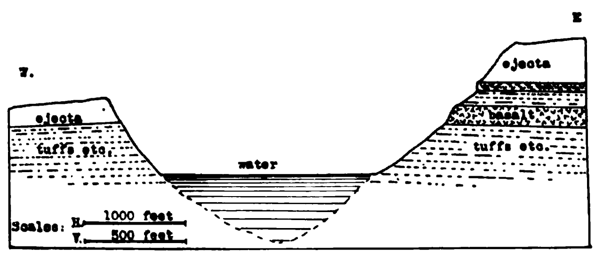

FIG. 3. SECTION ACROSS THE EXPLOSION CRATER OF ALXOXUCA IN PUEBLA, MEXICO, AFTER ORDONEZ.

La Preciosa, a smaller crater with lower surrounding ridge, also contains a lake said to be 275 feet deep. Its rim consists of a mass of ejected material somewhat irregularly distributed. The hole is in the tuff of the plain. Quecholac, which lies out on the plain some distance from the others, is about three fifths of a mile in diameter, with low encircling ridge 80 to 160 feet high. This ridge consists of ejecta, mainly cinders, lapilli and pumice, and a few rocks of the older formations in irregular sheets dipping gently outward. The underlying strata are not exposed. The lake is 300 feet deep.

The craters about Alxoxuca are on the plain at the foot of a volcanic ridge, but the materials in the walls and slopes are entirely of the tuffs which make up the plain. The craters are close to cones from which lava flowed recently, at one place overlapping the ejecta from the explosion craters. The principal crater, known as Alxoxuca, is somewhat more than a half mile in diameter, and the lake which it contains is 200 feet deep. The cross section, Fig. 3, shows the principal features on a west to east line. Two lava sheets are intercalated in the tuff on the east side, which rises considerably higher than the west side. The encircling rim consists, as in other craters, of fine ejecta containing many basalt fragments. The deep large crater of Tecuitlapa contains, as shown in Fig. 4, a conical mass of basalt and

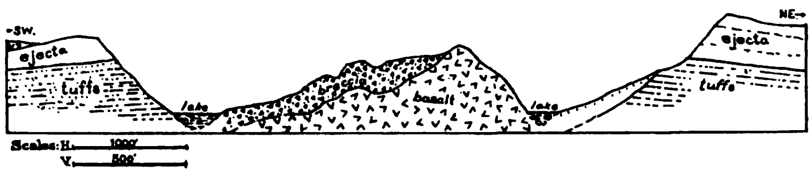

FIG. 4. SECTION ACROSS THE EXPLOSION CRATER OF TECUITLAPA IN PUEBLA, MEXICO, AFTER ORDONEZ.

breccia with three small craters, a feature very similar to Zuñi Lake in New Mexico. Steep walls rise from the central lake to the crest of the encircling ridge of ejecta which is 300 feet high and slopes gently to the adjoining plain. The interior cone and its craters are clearly of more recent age than the large crater and undoubtedly represent a final stage of the volcanic activity.

Two other craters, five miles east of Alxoxuca, are known as Xalapazco Grande and Xalapazco Chico. They contain no water. As shown in Fig. 5, they are less than a half mile in diameter, but the

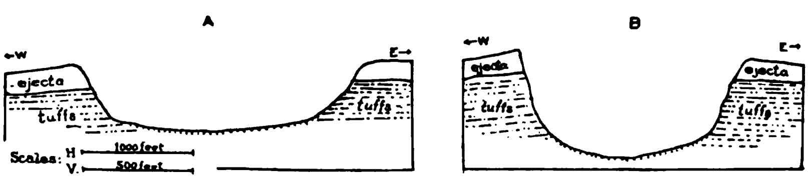

FIG. 5. *A*. SECTION ACROSS THE CRATER, AXALAPAZCO GRANDE. *B*. SECTION ACROSS THE CRATER, AXALAPAZCO CHICO, PUEBLA, MEXICO, AFTER ORDONEZ.

encircling rim does not rise high above the plain. The larger crater is 220 feet deep, and the smaller one nearly 400 feet. As in the case of the others, they are blown out through andesitic tuffs constituting the general valley floor and the rims consist of a large volume of fine ejecta containing much basaltic material. Ordoñez suggests that at the time of eruption a large volume of water was ejected with the

fine materal which would account for the irregular bedding in the ejecta in the encircling ridges.

Other explosion craters in south central Mexico have been described by Ordoñez, notably the fine group of eleven in the Valle de Santiago[4] and the crater at Xico,[5] near Mexico. These craters are in a plain underlain by tuffs and the beds adjoining the holes are not disturbed. The craters are surrounded by ridges of ejecta and all are the products of a similar cause, but in some cases two or more stages of development are apparent. The largest is more than a mile in diameter.

An explosion crater at Tacámbaro, in Michoacán, has been described by Rubio.[6] It contains a lake nearly a half mile in diameter, and the surrounding ridge of ejecta is more than 500 feet high on one side. The walls are basalt and the ejecta are ash, lapilli and tuff, with rock fragments.

Hornaday[7] and Lumholtz[8] have described a group of remarkable explosion craters in the northern part of Sonora, Mexico, fifteen to

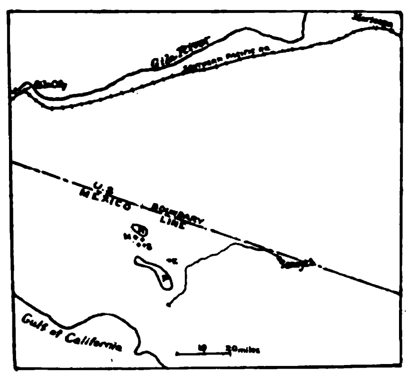

FIG. 6. MAP OF PART OF SONORA DESERT IN MEXICO AND ARIZONA, showing location of craters near Pinacate Mountains, after G. Sykes. *P*, Pinacate Mountains; *H*, Hornaday Mountains; +, craters; *S*, Sykes Crater; *M*, MacDougal Crater; *E*, Crater Elegante.

twenty-five miles south of the International Boundary line, about 100 miles southeast of Yuma, Arizona. This area is shown in the following map:

[4] "Les volcans du valle de Santiago," por E. Ordoñez, Soc. Antonio Alzate Mems., Vol. 14, pp. 299–326, pls. IV.–IX., 1897. Also "Les Crateres d'explosion de Valle de Santiago," por E. Ordoñez, Guide des Excursions Xe Cong. Geol. Int., Mexico, 1906, XIV., Excursion du Nord, 9 pages, plate.

[5] "Los crateros de Xico," *Bol. Soc. Geol. Mexicana*, Tomo 1, pp. 19–24, 1905.

[6] "El Axalapazco de Tacámbaro," por P. O. Rubio, *Bol. Soc. Geol. Mexicana*, Tomo 2, pp. 65–69, 1906.

[7] "Camp Fires on Desert and Lava," by W. T. Hornaday, Scribner's, 1908.

[8] "New Trails in Mexico," by Carl Lumholtz, Scribner's, 1912.

One of these craters in the plain 2½ miles northeast of Tinaja de los Papagos was named Sykes Crater by Hornaday. According to Lumholtz it had been visited by Sr. Y. Bonillas of Nogales in 1882. Sykes, who was geographer of Hornaday's expedition, found that the depth of the crater is 750 feet, its diameter at bottom 1,400 feet, and the bottom is 150 feet above sea level. A view of this great hole is given in Fig. 7. Lumholtz states that the rim is 130 feet high where

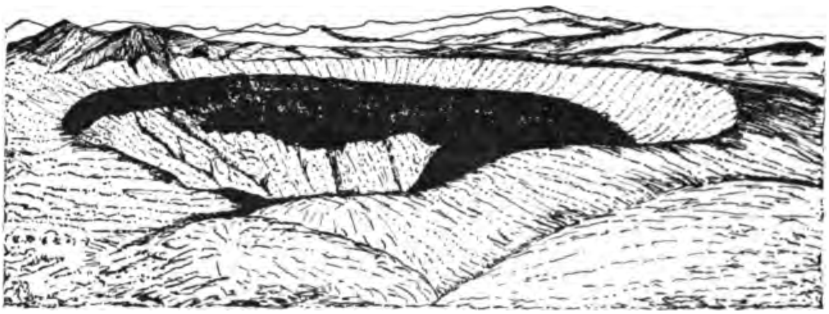

FIG. 7. SYKES CRATER, IN SONORA, MEXICO. Looking southeast. Pinacate Mountains in distance. After a colored view by Hornaday.

he crossed it. It evidently consists of ejecta and Hornaday states that in places the apex of the rim is "sandstone formed by the fusing of masses of volcanic sand under the influence of intense heat" and regards the material as having been thrown out of the crater.

Another great crater in the same vicinity has been named MacDougal Crater by Hornaday. It is in the lava plain a short distance southwest of the foot of Hornaday Mountains. A view of this hole, from a photograph kindly supplied by Mr. Charles Sheldon, is given in Fig. 8. The diameter of the bottom is 3,600 feet and depth below

FIG. 8. MACDOUGAL CRATER, LOOKING SOUTHWEST FROM TOP OF HORNADAY MOUNTAINS, SONORA, MEXICO. Photo by C. Sheldon, 1916.

rim 400 feet. Its bottom is about 50 feet above sea level. The walls are mostly very steep and there is the usual surrounding rim of ejecta.

Lumholtz found a fine large circular crater in the lava plain a short distance northeast of Sierra del Pinacate, to which he has given the name Crater Elegante. It is six miles northeast of the central peak, near the edge of a plain covered by a thin lava sheet. He estimates its depth at 800 feet and a rough measurement gave a mile

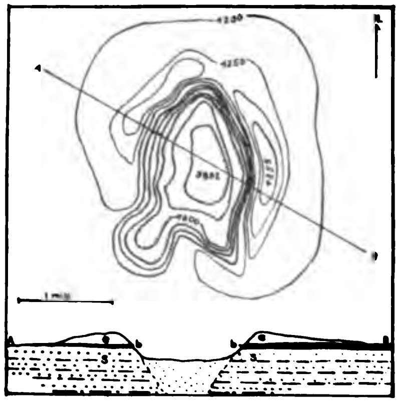

FIG. 9. CONTOUR MAP AND CROSS SECTION OF KILBURN CRATER, NEW MEXICO. Contour interval 50 feet, datum sea level. *s*, stratified sand; *b*, basalt; *e*, ejecta.

diameter. It is rimmed by a ridge rising about 150 feet above the surface of the plain. The bottom is flat and talus rises about half way up the sides. The view given by Lumholtz shows alternations of regularly bedded material.

The Afton craters in southern New Mexico, thirty miles north-

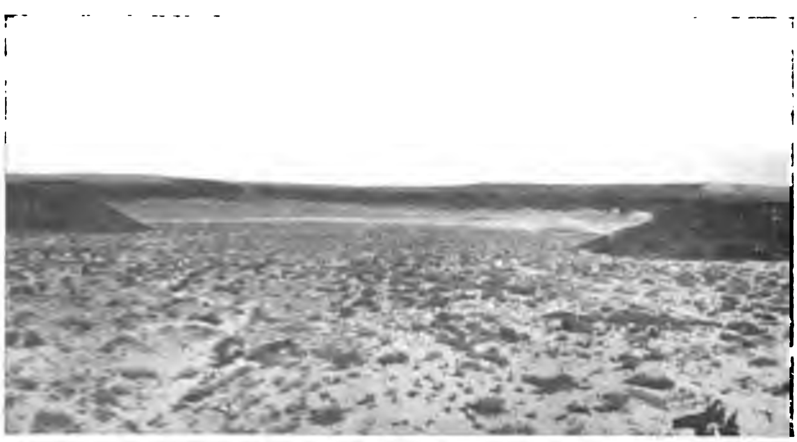

FIG. 10. LOOKING NORTHEAST INTO KILBURN CRATER NEAR AFTON, in southern New Mexico. The black streak is a thin sheet of lava much older than the hole. Note ranch to right of center of view. Photographed by W. T. Lee.

west of El Paso, described by Lee,[9] are closely similar to the craters in Mexico described above. They are in a level plain of thick stratified river deposits capped by a thin sheet of late basalt. One is a mile in diameter and about 150 feet deep; the other, two miles north, is two miles long and about 250 feet deep. Both are circled by rims of ejecta rising 10 to 200 feet above the plain. The inner slopes are steep and the outer slopes gentle. The ejecta, which lies on a fifteen-foot sheet of basalt, consists of sand, cinders, pumice, and blocks of basalt, and in part, especially near the base, shows irregular bedding with low outward slope. All came from below and was thrown out by an explosion, but the volume is much less than that of the craters. The configuration and structure of the larger crater is shown in Fig. 9. A view is given in Fig. 10.

Lee suggests that the explosion was caused by formation of steam generated by lava forced into the water-saturated sands.

The crater holding Zuñi Salt Lake is in the central-western part of New Mexico, about 75 miles south of Gallup. When I published a description of this feature in 1905,[10] I was inclined to believe that it was due partly to volcanic action and partly to subsidence caused by removal of underlying salt beds by solution. After comparing it with the conditions in other regions, I feel convinced it is an explosion crater. Some of the features are shown in Figs. 11 and 12. It is

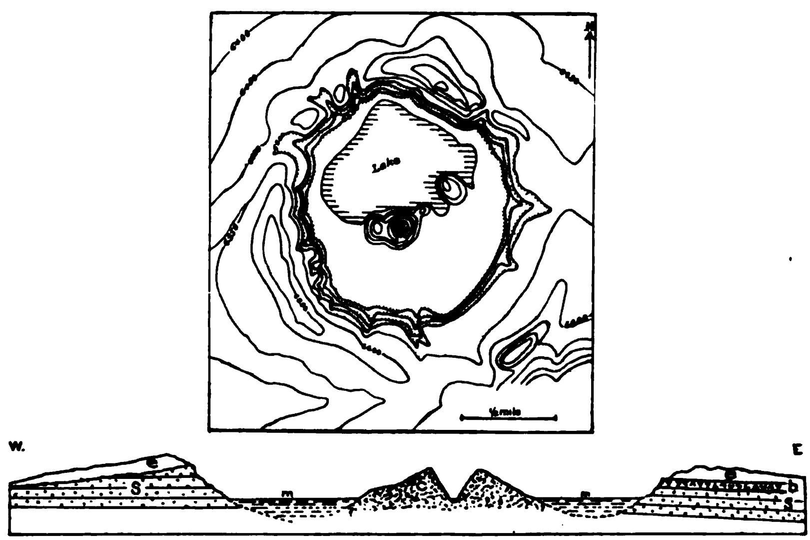

FIG. 11. CONTOUR MAP AND CROSS SECTION OF ZUÑI SALT LAKE IN WEST CENTRAL NEW MEXICO. *e*, ejecta; *s*, cretaceous sandstone; *c*, cinder cone; *m*, mud and salt recently deposited by the lake.

[9] "Afton Craters of Southwestern New Mexico," by W. T. Lee, *Bull. Geol. Soc. Am.*, Vol. 18, pp. 211–220, pls. 3–4, 1907.

[10] "The Zuñi Salt Lake," by N. H. Darton, *Jour. Geol.*, Vol. 13, pp. 185–193, 1905.

Fig. 12. Looking North across the Crater Holding Zuni Salt Lake, New Mexico. Large cinder cone with crater is in center; walls and plateau of Cretaceous sandstone surmounted by encircling ridge of ejecta, in mid-distance.

FIG. 13. BIRD'S-EYE VIEW OF CRATER MOUND, ARIZONA. Looking northwest San Francisco Mountains in the distance to the right.

on this plantation, as figures on these crops are not available for this particular region.

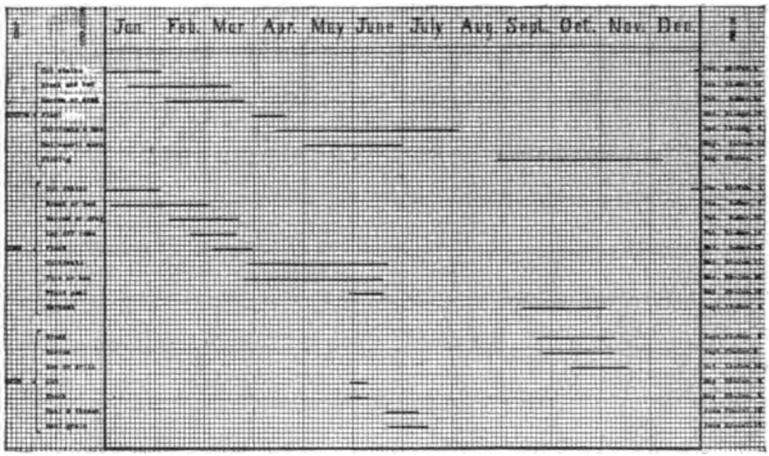

CHART I.

The following table gives the labor requirements on this plantation, distributed in terms of days of adult labor required per month, for 823 acres of cotton, 657 acres of corn, and 200 acres of oats.

As an example, the operation of cutting stalks in cotton fields will serve to show how this distribution was made. Cutting stalks requires .13 man days per acre. On 823 acres this would amount to a total of 107 days. The period when this work is done is from December 28 to February 4. On the basis of 12.6 days during December when field work is possible, there would be available 1.21 days for field work for the 3 days in December. There would be 12 days available for January and 1.7 days for the 4 days in February. The 107 days of adult labor required would have to be done in a period of the sum of these available days, or a total of 14.91 days. To do this would require the time of 7.17 adults. By assigning the days per month on the basis of the days available per month for field work, there is obtained a requirement of 9 days of man labor in December, 86 in January and 12 in February for cutting stalks. The operations for all crops were figured in this manner.

The accompanying chart (see chart II.) illustrates the relation of malaria to crop production by comparing the available labor, the labor required for the crops, including the labor for boll-weevil control in cotton, with the time lost through malaria. It shows that malaria is a serious handicap to the plantation during the months of May, June, September and October. During these months the operations are cultivating, hoeing, boll-weevil control and harvest. Maximum labor is required during all of these periods. There is a total loss of 660 adult days through malaria, in excess of any surplus time, during these 4 months.

DAYS ADULT LABOR REQUIRED FOR CROPS, DISTRIBUTED BY MONTHS[3]

Crop	Operations	Jan.	Feb.	March	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Totals
Cotton	Cut stalks	86	12	...	.....	.....	.....	.....	...	.....	.....	.....	9	107
	Break and bed	142	257	161	.....	.....	.....	.....	...	.....	.....	.....	...	560
	Harrow or drag	...	52	63	.....	.....	.....	.....	...	.....	.....	.....	...	115
	Plant	...	...	5	102	.....	.....	.....	...	.....	.....	.....	...	107
	Cultivate and hoe	...	...	...	551	1,164	1,216	1,367	171	.....	.....	.....	...	4,469
	Pick and haul	...	...	...	.....	.....	.....	.....	112	1,614	1,638	1,406	810	5,580
	Total for crop	228	321	229	653	1,164	1,216	1,367	283	1,614	1,638	1,406	819	10,938
	Boll weevil control	...	...	...	.....	451	471	.....	...	.....	.....	.....	...	922
	Total for cotton	228	321	229	653	1,615	1,687	1,367	283	1,614	1,638	1,406	819	11,860
Corn	Cut stalks	62	7	...	.....	.....	.....	.....	...	.....	.....	.....	10	79
	Break or bed	43	448	35	.....	.....	.....	.....	...	.....	.....	.....	...	526
	Harrow or drag	...	49	56	.....	.....	.....	.....	...	.....	.....	.....	...	105
	Lay off rows	...	29	56	.....	.....	.....	.....	...	.....	.....	.....	...	85
	Plant	...	...	92	.....	.....	.....	.....	...	.....	.....	.....	...	92
	Cultivate	...	...	38	247	295	215	.....	...	.....	.....	.....	...	795
	Thin or hoe	...	...	48	225	270	160	.....	...	.....	.....	.....	...	703
	Plant peas	...	...	...	.....	9	70	.....	...	.....	.....	.....	...	79
	Harvest	...	...	...	.....	.....	.....	.....	...	187	336	29	...	552
	Total for corn	105	533	325	472	574	445	.....	...	187	336	29	10	3,016
Oats (Thrashed)	Break	...	...	...	.....	.....	.....	.....	...	25	84	19	...	128
	Harrow	...	...	...	.....	.....	.....	.....	...	5	31	8	...	44
	Sow or drill	...	...	...	.....	.....	.....	.....	...	.....	11	7	...	18
	Cut	...	...	...	.....	8	24	.....	...	.....	.....	.....	...	32
	Shock	...	...	...	.....	15	49	.....	...	.....	.....	.....	...	64
	Haul and thrash	...	...	...	.....	.....	68	74	...	.....	.....	.....	...	142
	Haul grain	...	...	...	.....	.....	12	26	...	.....	.....	.....	...	38
	Total for oats	...	...	...	.....	23	153	100	...	30	126	34	...	466
Summary	Total for cotton	228	321	229	653	1,615	1,687	1,367	283	1,614	1,638	1,406	819	11,860
	Total for corn	105	533	325	472	574	445	.....	...	187	336	29	10	3,016
	Total for oats	...	...	...	.....	23	153	100	...	30	126	34	...	466
	Grand total	333	854	554	1,125	2,212	2,285	1,467	283	1,831	2,100	1,469	829	15,342

Making allowance for the time lost on days when field work was not possible, there was a loss of 420.75 adult days which amounted to actual neglect. During these 4 months there are 76.5 days available for field work. The loss represents that of 5.5 adults out of a total of 90 available adults. The actual available adult time per family is 1.21 adults. The time lost is the equivalent to that of 4.54 families. Adding to this the effect of malaria on the efficiency of the labor, amounting to the time of 9.25 families, the survey shows that in the absence of malaria this plantation could operate with the same net returns on the labor of 60.21 tenant families, instead of the 74 families required in the presence of malaria.

[3] On the basis of 823 acres of cotton, 657 acres of corn, and 200 acres of oats.

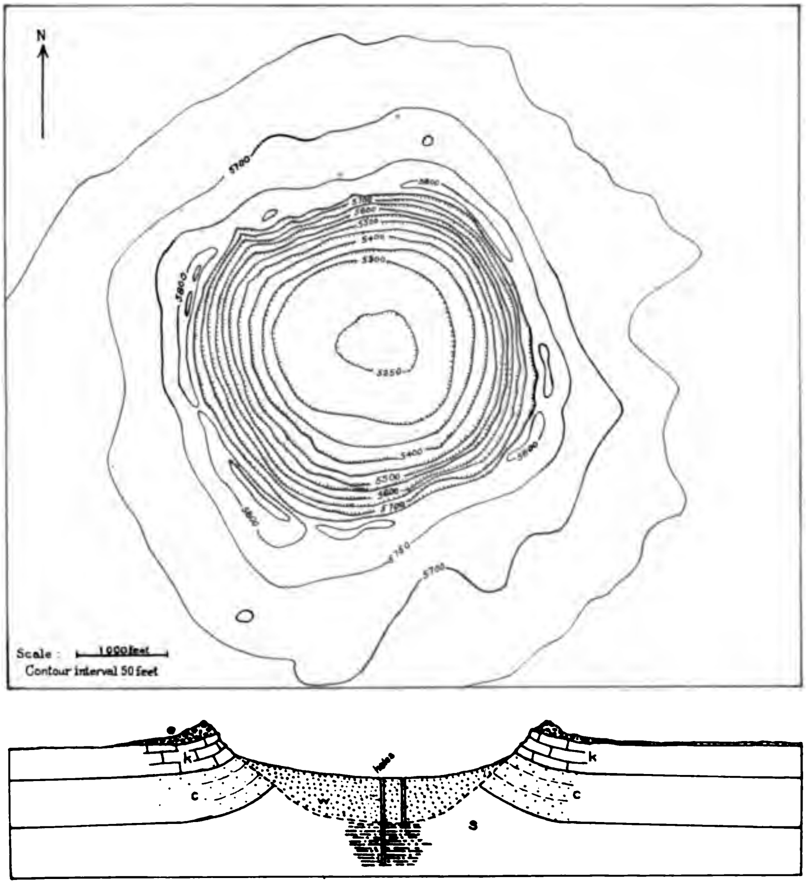

FIG. 14. CONTOUR MAP AND CROSS SECTION OF CRATER MOUND, ARIZONA. *e*, ejecta; *K*, Kaibab limestone; *C*, Coconino sandstone; *S*, Supai red sandstone; *w*, sand, etc.

about a mile in diameter, 150 feet deep, and encircled by a wide rim of ejecta consisting mainly of fine scoria containing fragments of the sedimentary rocks which underlie the region. Part of the material is stratified and cross bedded. The walls of the crater are Cretaceous

FIG. 15. A MODEL OF CRATER MOUND, ARIZONA. Constructed for G. K. Gilbert from a detailed topographic map by Marcus Baker.

FIG. 16. CRATER REMARKABLY LIKE CRATER MOUND IN APPEARANCE, caused by explosion of a "Mine" in the trenches in northern France in 1915.

sandstone, in part capped by a lava sheet of moderate antiquity. From the lake occupying part of the center of the crater rise two small cones of scoria, one with deep crater, and evidently very recent. The ejected material covers a wide area on the rim and beyond, and while it is much too small in volume to fill the crater, probably a large amount has been

FIG. 17. PART OF THE GREAT RIM OF FRAGMENTS OF LIMESTONE AND SANDSTONE EJECTED FROM CRATER MOUND, ARIZONA. Photo by G. K. Gilbert. Many of the masses weigh more than 5,000 tons, the largest 20,000 tons and the total amount of ejecta is about 250 million tons or approximately sufficient to fill the hole.

FIG. 18. LARGEST BLOCK IN THE EJECTA ON RIM OF CRATER MOUND, ARIZONA. A mass of limestone 60 feet in diameter weighing about 20,000 tons. Photo by G. K. Gilbert.

removed by erosion. Undoubtedly its bedded condition was caused by a simultaneous outburst of water.

Crater Mound, or Coon Butte as it was originally named, is so well known that I will not review it in detail and there is nothing new to add to previous descriptions.[11] Some of the salient features are shown in map and cross section, Fig. 14, and the views in Figs. 13, 15, 17 and 18. Its origin has not been ascertained and it remains one of the greatest enigmas in nature. The idea that it was caused by impact of a meteoric iron 50 to 100 feet in diameter has not yet been substantiated by borings, shaft and the survey of magnetic declination. It is interesting to compare this crater with the illustrations of explosion craters given above and the close similarity of many features is very suggestive in connection with Gilbert's original suggestion that Crater Mound was caused by a steam explosion.

[11] Gilbert, G. K., "The Origin of Hypotheses Illustrated by the Discussion of a Topographic Problem," Geol. Soc. Wash., Presidential Address, 1895, and *Science*, N. S., Vol. 3, pp. 1–12, 1896. Barringer, D. M., and Tighlman, B. C., "Coon Mountain and Its Crater," *Phil. Acad. Sci., Proc.*, 1906, pp. 861–914. Merrill, G. B., "The Meteor Crater of Canyon Diablo, Arizona. Its History, Origin and Associated Meteoric Irons," *Smith. Miscell. Coll.*, Vol. 50, Pt. 4, pp. 461–498, 1908. Barringer, D. M., "Meteor Crater in Northern Central Arizona," *Nat. Acad. Sci.*, Nov. 16, 1909, 24 pp., pls. Darton, N. H., "A Reconnaissance of Parts of Northwestern New Mexico and Northern Arizona," U. S. Geol. Survey, Bull. 435, 1910.

THE RELATION OF MALARIA TO CROP PRODUCTION

By D. L. Van Dine

Bureau of Entomology, United States Department of Agriculture

THE principal effects of malaria upon farming are a reduction in the net profits on the crops grown and reduced values from the non-development of farm lands. Herrick (1903) mentions these losses, as applied to southern agriculture, and Howard (1909) emphasizes the economic loss from malaria by figures which are startling. He estimates that there is an annual loss in the United States through this disease of not less than $100,000,000.

The rural nature of malaria places the larger portion of the loss from the disease upon the farming class. The disease is more prevalent in the south than in other regions of the United States. The higher prevalence in the south is due to the larger areas of swamp and undrained lands, and lands subject to overflow which offer favorable breeding-places for the mosquitoes that convey the disease, to the longer season of high temperatures which favors mosquito development and which increases the length of the active season of the disease, and to the presence in larger numbers of an indifferent race which is tolerant of the disease. Although the losses from malaria have been appreciated for many years, the exact manner in which the disease operates against farm profits is not generally understood.

In 1913 the Bureau of Entomology undertook a detailed study of the relation of malaria to agriculture in the south. The ultimate object of the study is the prevention of malaria on the farm. The investigation is based on the idea that the prevention involves measures for the control of malaria mosquitoes which are practicable under the usual farming conditions. In the absence of definite information on the relation of the disease to farming, the primary work dealt mainly with the exact manner in which malaria operates against the net profits from farm crops. The study is an intensive one and its scope extends no further than the strictly agricultural and biological phases of the problem. The effort is to obtain concrete and fundamental information as a basis for an extensive application of measures for prevention. It is believed that the first step is to secure definite data on the manner in which malaria affects agriculture.

During the course of the investigation it has been determined that the important losses from malaria on a plantation are sustained through the loss in time and the reduced efficiency of the labor at the season of the year when the labor is most needed to work and to harvest the crops.

The prevailing system of plantation labor in the south is the negro tenant system, and the prevention of malaria among the tenants is considered the most important point in the problem of preventing the disease on a plantation. In the tenant system, the family is the unit in contrast to the day-wage system, where the individual is the unit. The family was, therefore, made the unit in the study.

The figures in this paper are based on the conditions that obtained during the season of 1914. The survey work included a detailed study of the 74 tenant families on a plantation and the amount of malaria among them in a region where the plantation operations and endemic malaria are typical. The plantation cultivated 1,800 acres of land, 1,191 acres by the tenant system and 609 acres under the direct supervision of the plantation management by labor drawn from the tenant families on a day-wage basis. The tenants averaged 16 acres per family. The 74 families show a total of 299 individuals, or an average of 4 persons per family.

The crops grown on the plantation consisted of 743 acres of cotton and 448 acres of corn under the tenant system and 80 acres of cotton, 209 acres of corn, 200 acres of oats, 70 acres of cow-peas and 50 acres of lespedeza hay under the day-wage system.

All time was reduced to adult time or man days of labor. The time of a male over 18 years of age was figured as full time, a male from 12 to 18 years as one half adult time and from 8 to 12 years as one fourth. The time of a female was figured as one half the time of a male. No account was taken of the time under 8 years of age. Reducing all the available labor on the plantation to adult time, there is an equivalent of 2 adults to each of the 74 tenant families.

The actual time lost through malaria consisted of 970 days for those treated by the plantation physician, 487 days in those cases not reporting to the physician, and 385 days lost by non-malarial members of the families in attending those who had the disease. There was a total loss of 1,842 days. This reduced to adult time, not taking account of illness in members of the families under eight years of age, amounts to 1,066 days of adult time from May to October, inclusive. The time lost averaged 14.4 adult days for each family. There were 166 cases of malaria in 138 persons out of the total of 299 members of the tenant families. There was a loss of time equivalent to 6.42 adult days for each case of malaria. The seasonal distribution of the cases of malaria was as follows: May, 15 cases; June, 31 cases; July, 25 cases; August, 38 cases; September, 36 cases, and October, 21 cases. The number of adult days lost through malaria, then, is 96 days for May, 199 days for June, 161 days for July, 244 days for August, 231 days for September and 134 days for October.

The effect of loss of time upon the crops can be measured by the

ratio of the time lost through malaria to the difference between the available labor and labor requirements of the crops. It must be conceded that any loss of labor from any cause in the face of any surplus labor that exceeds the time lost, can not be considered as operating against the crops. In the case of no surplus labor, or an actual deficiency, any time lost through malaria reacts at once upon the crops, the seriousness of the neglect to the crops depending upon the period in the planting, cultivating or harvesting the crops that the lost time occurs. It will be shown that the time lost through malaria during at least four months of the year falls at periods when there is a deficiency of labor and when the demands of the crops for labor are greatest. For cotton, the principal crop, these periods are chopping and hoeing, boll-weevil control and picking. Any neglect at these periods is a very serious matter and might mean total failure of a crop.

The available days for field work depend not only upon the number of adult laborers on the plantation, but also upon the available days per month when field work is possible. These two factors decide the available days of adult labor for field work. Mr. M. B. Oates of the Office of Farm Management of the Department of Agriculture has furnished the writer the following estimate of available days per month for field plantation work as determined by a study of estimates obtained by him from 50 plantation managers in the Red River region of northwest Louisiana.[1]

Month	Days	Month	Days	Month	Days	Month	Days
Jan......	12.0	April.....	15.3	July.....	21.5	Oct......	19.7
Feb......	11.9	May......	18.3	Aug......	21.0	Nov......	16.9
March...	14.5	June......	19.1	Sept......	19.4	Dec......	12.6

The fallacy of figuring total days of adult labor per month on a basis of a 30-day month is evident. The factors of Sundays, holidays and climate determine the number of days available for field work during any month. The error would be as great to reduce all labor on the plantation to terms of adult labor and use this figure in obtaining the days of adult labor available. With 74 families averaging 2 adults per family there would be indicated a total of 148 adult days for every day in the year, 4,440 days adult labor available per month or the great total of 53,280 man-days of labor per year. Mr. Oates, on the basis of estimates from 72 plantations, finds that in this region 13.29 adult days of man labor, not including horse labor, are required per acre of cotton. On this basis the above figure shows that this plantation has an amount of labor sufficient to work over 3,200 acres of cotton, a condition which does not exist. The above table by Mr. Oates eliminates the error in

[1] The region included in the estimates is within the 50-inch rain belt. Madison Parish, where this study is located, has a normal rainfall of 51 inches.

days available for field work. It remains to consider the error in number of adults available for labor.

The object is to determine the relation of time lost through malaria to the total time available and to the time required by the crops. In considering the time available it will be necessary to eliminate the effect of malaria upon the efficiency of the labor. Howard (1909) estimates that one fourth of the productive capacity of an individual suffering with an average case of malaria is lost. One hundred and thirty-eight persons out of a total of 299 suffered from malaria during the crop season. Not taking account of the cases in children under 8 years of age and the time lost by adult non-malaria persons in attending those who were sick, the equivalent of the time of the malaria people is equal to the time of 74 adults. A reduction of 25 per cent. in the efficiency of 74 adults equals the total loss of the time of 18.5 adults. An average of 2 adults per family would indicate a loss equivalent to the total time of 9.25 families.

On the basis that every man, woman and child worked every available day in the field there would be available the time of 64.75 families. To figure on this basis would be as great an error as it would be to figure that there were 30 days available for field work every month in the year. There would be no day when every available person over 8 years of age would be in the field and all the persons in the field would not put forth maximum effort every day throughout the year. It is estimated that for these reasons the available labor would be reduced at least 25 per cent. This would mean that instead of 64.75 families, there would be only 48.57 families available. With an average of 2 adults per family, there appears to be available the equivalent of 97.14 adults. However, other factors act to reduce the available labor. Account must be taken of those who have passed the age limit for work in the field, the "pensioners" of the plantation. A funeral will keep practically all the laborers out of the field for all or a part of a working-day. Other diseases aside from malaria keep the laborers at home on working-days. It is estimated that the equivalent of one adult out of every ten would not be available for these reasons. The available man labor on the plantation has been figured on the basis of 90 adults.

Taking 90 adults as representing the available labor and using Mr. Oates's figures on the days available per month for field work, we have the following man days available per month for field work on this plantation.

Month	Days	Month	Days	Month	Days	Month	Days
Jan......	1,080	April......	1,337	July......	1,935	Oct......	1,773
Feb......	1,071	May......	1,647	Aug......	1,890	Nov......	1,521
Mar......	1,305	June......	1,719	Sept......	1,746	Dec......	1,134

fifth of its volume: for these researches Priestley received the Copley medal in 1773.

The details of the private life of Stephen Hales are neither numerous nor romantic. The son of Thomas, eldest son of Sir Robert Hales of Beckesbourn, Stephen was born in 1677 near the pleasant village of Beckesbourn in Kent, not far from Canterbury. His mother was Mary, daughter and heiress of Richard Wood, of Abbot's Langley. At the age of nineteen he went to Cambridge, being entered at Bene't College (now Corpus Christi), of which he became a fellow in 1703. In due time he graduated M.A. and he took his B.D. degree in 1711. His early scientific leanings may be inferred from his having studied anatomy, chemistry and botany as a recreation. Accompanied by William Stukeley, a fellow student, later M.D. and F.R.S., Hales is reported to have studied field botany on the Gog-Magog Hills and on Cherry Hunt Moor by the aid of Ray's catalogue of local plants, and also at this time to have made collections of fossils and of butterflies. It was as a student, too, that he contrived to make a cast in lead of the lungs of a dog. He did not neglect astronomy, for according to one account he constructed a "planetarium in brass" or, as it was later called, an "Orrery" on Newtonian principles. Having taken Holy Orders, Hales was presented in 1710 to the "perpetual curacy" of Teddington in Middlesex. Not long after he resigned his fellowship on being presented to the living of Porlock in Somerset; this he finally exchanged for that of Farringdon in Hampshire. The date of his marriage is uncertain: it is thought to have been in 1719; his wife died childless in 1721; Hales did not marry again. It was at Teddington that by far the greater number of his experiments were carried out. At his own expense he rebuilt the tower of the parish church of St. Mary's-in-the-Meadows. In 1718, at the comparatively early age of forty, Hales was elected into the Royal Society, and twenty-two years later was awarded the Copley medal—the highest honor in the gift of that learned body. Until within a year or two of his death he communicated the results of his manifold researches in the form of papers to the Royal Society. He published, however, in book form several treatises: his "Vegetable Statics" saw the light in 1726, and the "Hæmostatics" or Volume II. in 1733. Volume I. is dedicated to "His Royal Highness George Prince of Wales" and Volume II. "To the King's Most Excellent Majesty." This "George, Prince of Wales," and the "King's Most Excellent Majesty" are the same person, for in 1726 George I. was still reigning, but by 1733 his son George, who had been Prince of Wales, was now George II.

Although, then, Hales wrote extensively on vegetable and animal physiology, chemistry and medicine—for he discoursed on the alleged virtues of tar-water and investigated solvents for stone in the bladder—it is as a pioneer sanitarian that he must ever live in our grateful

Herrick (1903) says, in writing of the effect of malaria upon southern agriculture, that "to induce a people to use a remedy it must first be shown that a remedy is very much needed." It is the purpose of the Department of Agriculture to place the prevention of malaria on the farm upon a business basis. It remains to show what malaria means to a cotton planter in so many dollars and cents.

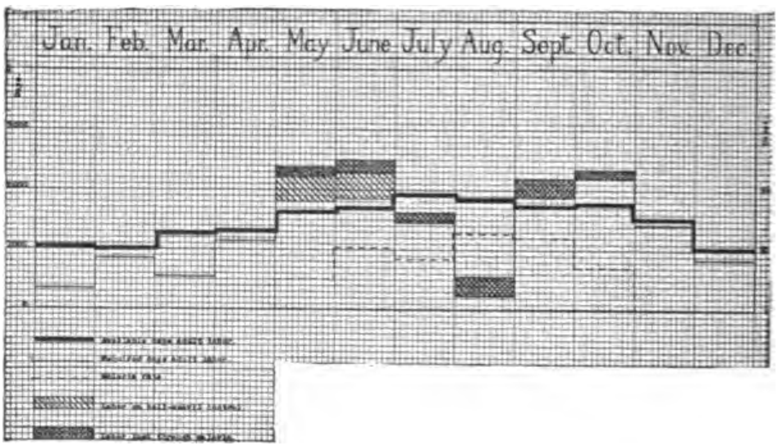

CHART II.

Each family cultivated an average of 16 acres. The plantation depended upon the tenants for labor to cultivate an average of 8.23 acres each on the day-wage basis. This amounts to a total of 24.23 acres to be cultivated by the labor represented in each tenant family, an equivalent of 13.51 acres of cotton. The total loss of the time of 13.79 families is equal to that of the total crop on 186.3 acres of cotton. With an average yield of one half of a bale of cotton per acre, this would equal a total loss of 93.15 bales of cotton. Allowing $70 a bale for the lint and seed, this would amount to $6,520.50.

The amount of share varies under the tenant system. In general, though, the plantation management furnishes the land, cabin, mules, feed, implements and fertilizer, and advances to the tenant subsistence and seed. Under this arrangement the plantation receives one half of the crop. Against all this the tenant places only his labor. Any reduction in the yield falls largely upon the owner, since he loses not only his one half of the crop, but a proportion of the advances. In a failure of the crop, the owner loses his one half and the use of the land, cabin, mules and implements, plus all advances to the tenant. The most that the tenant stands to lose is his labor. Not allowing for days when field work was impossible and on the basis of the prevailing day wage of $1.00 per day, this amounts to $660. The net loss to the owner is then $5,860.50.

The actual available adult time in each family equals 1.21 man days. The actual number of available days for field work during the four months under consideration equals 76.5 days. A loss of time equivalent to the total loss of 13.79 families is equal to the loss of 1276.47 man days during these periods, when there was no surplus labor. There were 420.75 days lost through sickness and a loss of 855.72 days due to reduced efficiency. Each day of neglect amounted to a total loss of $5.11, being a loss of $4.11 to the owner and $1.00 to the tenant. The conclusion is that a loss equivalent to one day of man labor through malaria on this plantation, when the crops were in need of attention, and when there was no surplus labor, amounted to a net loss of $5.11 in the crop returns. Approximately $2,200 was lost through sickness and $4,300 through inefficiency from malaria.

The above survey was made in Madison Parish, Louisiana. The common house-frequenting *Anopheles* in this region is *Anopheles quadrimaculatus* Say. *Anopheles punctipennis* Say is common in nature while *Anopheles crucians* Wied., was encountered only in very limited numbers. All three forms of the malaria parasite have been found to occur in this region, namely, tertian, estivo-autumnal and quartan, prevailing in the order named. The work was done in cooperation with the Maxwell-Yerger Co., Dr. Wm. P. Yerger, and Mr. Alexander Clark, Manager of Hecla plantation, Mound, La. The *Anopheles* determinations were made by Mr. F. Knab, of the U. S. National Museum. The blood examinations were made by Mr. J. K. Thibault, Jr., of this Bureau. Mr. Oates, of the Office of Farm Management of this department, furnished the data on the periods of the plantation operations, the available days per month for field work and the labor requirements of the crops.

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STEPHEN HALES, THE PIONEER IN THE HYGIENE OF VENTILATION

By D. FRASER HARRIS, M.D., D.Sc., F.R.S.C., F.R.S.E.

PROFESSOR OF PHYSIOLOGY IN DALHOUSIE UNIVERSITY, HALIFAX, NOVA SCOTIA

IT has happened again and again in the history of discovery that some of the most important advances in a particular science have been made by persons not engaged in the professional pursuit of that subject.

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There have been parallel cases in other sciences: the Marquis of Worcester, though not an engineer, invented the steam pump; Leeuwenhoek, though not a member of the medical profession, made discoveries of the most fundamental order in physiology and microscopical anatomy; Captain Cook, though neither a physician nor a biologist, investigated from the practical side the causes and incidence of scurvy with such excellent results to the health of sailors that he was awarded the Copley medal of the Royal Society in 1776; Lady Mary Wortley Montagu, the wife of the British ambassador at Constantinople, introduced inoculation for smallpox into England; Helmholtz, though not an oculist, invented the ophthalmoscope; Pasteur, though not a medical practitioner, introduced inoculation of attenuated virus for the cure of hydrophobia; and, in our own day, Metchnikoff, trained as a scientific zoologist, has exercised a most far-reaching influence on the doctrines of bacteriology and practical medicine.

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Herrick (1903) says, in writing of the effect of malaria upon southern agriculture, that "to induce a people to use a remedy it must first be shown that a remedy is very much needed." It is the purpose of the Department of Agriculture to place the prevention of malaria on the farm upon a business basis. It remains to show what malaria means to a cotton planter in so many dollars and cents.

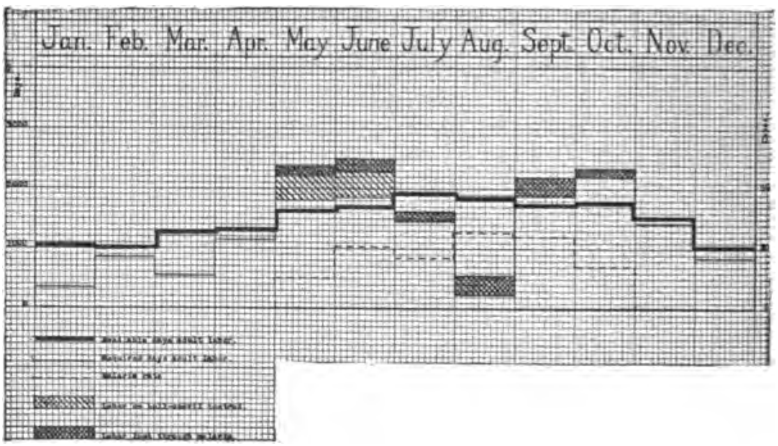

CHART II.

Each family cultivated an average of 16 acres. The plantation depended upon the tenants for labor to cultivate an average of 8.23 acres each on the day-wage basis. This amounts to a total of 24.23 acres to be cultivated by the labor represented in each tenant family, an equivalent of 13.51 acres of cotton. The total loss of the time of 13.79 families is equal to that of the total crop on 186.3 acres of cotton. With an average yield of one half of a bale of cotton per acre, this would equal a total loss of 93.15 bales of cotton. Allowing $70 a bale for the lint and seed, this would amount to $6,520.50.

The amount of share varies under the tenant system. In general, though, the plantation management furnishes the land, cabin, mules, feed, implements and fertilizer, and advances to the tenant subsistence and seed. Under this arrangement the plantation receives one half of the crop. Against all this the tenant places only his labor. Any reduction in the yield falls largely upon the owner, since he loses not only his one half of the crop, but a proportion of the advances. In a failure of the crop, the owner loses his one half and the use of the land, cabin, mules and implements, plus all advances to the tenant. The most that the tenant stands to lose is his labor. Not allowing for days when field work was impossible and on the basis of the prevailing day wage of $1.00 per day, this amounts to $660. The net loss to the owner is then $5,860.50.

The actual available adult time in each family equals 1.21 man days. The actual number of available days for field work during the four months under consideration equals 76.5 days. A loss of time equivalent to the total loss of 13.79 families is equal to the loss of 1276.47 man days during these periods, when there was no surplus labor. There were 420.75 days lost through sickness and a loss of 855.72 days due to reduced efficiency. Each day of neglect amounted to a total loss of $5.11, being a loss of $4.11 to the owner and $1.00 to the tenant. The conclusion is that a loss equivalent to one day of man labor through malaria on this plantation, when the crops were in need of attention, and when there was no surplus labor, amounted to a net loss of $5.11 in the crop returns. Approximately $2,200 was lost through sickness and $4,300 through inefficiency from malaria.

The above survey was made in Madison Parish, Louisiana. The common house-frequenting *Anopheles* in this region is *Anopheles quadrimaculatus* Say. *Anopheles punctipennis* Say is common in nature while *Anopheles crucians* Wied., was encountered only in very limited numbers. All three forms of the malaria parasite have been found to occur in this region, namely, tertian, estivo-autumnal and quartan, prevailing in the order named. The work was done in cooperation with the Maxwell-Yerger Co., Dr. Wm. P. Yerger, and Mr. Alexander Clark, Manager of Hecla plantation, Mound, La. The *Anopheles* determinations were made by Mr. F. Knab, of the U. S. National Museum. The blood examinations were made by Mr. J. K. Thibault, Jr., of this Bureau. Mr. Oates, of the Office of Farm Management of this department, furnished the data on the periods of the plantation operations, the available days per month for field work and the labor requirements of the crops.

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STEPHEN HALES, THE PIONEER IN THE HYGIENE OF VENTILATION

BY D. FRASER HARRIS, M.D., D.Sc., F.R.S.C., F.R.S.E.

PROFESSOR OF PHYSIOLOGY IN DALHOUSIE UNIVERSITY, HALIFAX, NOVA SCOTIA

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health it is not too much to say that as a benefactor of mankind, he is conspicuous in the first half of the eighteenth century. It would be difficult to mention the name of any other person co-equal with his. We know very little indeed of his capabilities as a pastor of men's souls, but it is certain that he had great solicitude for their bodies; he introduced a water-supply into the village of Teddington, and it appears that he actually contrived to ventilate its parish church. His pamphlet against the abuse of alcohol is probably the first of its kind in English—"A friendly admonition to the drinkers of gin, brandy and other spirituous liquors." This, published in 1734, alone enables him to rank as a pioneer in the advocacy of measures of practical hygiene. Hales had grasped the very essence and kernel of the principle of ventilation, *that air must be changed,* whether air for plants or for animals, air over corn in granaries or over water stored for drinking purposes or air enclosed in hot-houses, or air in mines, or in the holds of ships, or in prisons, or around timber or gunpowder; air must be changed. He knew that fresh air was inimical to putrefaction, mouldiness of every kind; he invented an apparatus for blowing air through drinking water stored in ships. On long voyages in the "old wooden walls" such water became putrid: Hales showed that it could be made sweet again if only enough air could be blown through it. We *now* know what was going on, namely the oxidation of organic matter; but Hales died in 1761, thirteen years before oxygen was discovered. It is interesting to note that Hales had the most definite conceptions as regards this necessity for oxygen in ventilation, without knowing what it was that sustained life, and without knowing, in anything like its fulness, the meaning and importance of Joseph Black's discovery that animals exhaled carbon dioxide from their lungs. Black's discovery was published in 1754, some seven years, indeed, before Hales died; but it is certain that Hales was not indebted to Black; on the contrary, it is not as widely known as it might be that Black was profoundly indebted to Hales. Black wrote:

> I was partly led to these experiments by some observations by Dr. Hales, in which he says that breathing through diaphragms of cloth dipped in alkaline solution made the air last longer for the purposes of life.

Before we further examine the value of the contributions made by Hales to the hygiene of ventilation, it will be well to trace the order of the discoveries of the gases of the atmosphere without which, of course, in the long run no scientific basis for the study of the problems of ventilation could have been arrived at. Carbon dioxide was discovered under the name of gas sylvestre by the Belgian chemist J. B. van Helmont (1577 to 1644) about the year 1640. Having burnt a known weight of wood, he noticed that only about one sixtieth of the original weight remained in solid form. The other fifty-nine sixtieths he regarded as

something volatile to which he gave the name of "gas," a word he coined on purpose to designate this "spirit" of wood and other kindred spirits. Gas sylvestre, because it came from or was produced by the burning of wood, was the first name under which carbon dioxide became a chemical concept in the minds of men of science.

The next contributions to accurate notions about breathing and hence about the necessity of ventilation, were made by Thomas Willis (1621 to 1675), who distinctly laid it down that three things cooperated in the act of respiration. These were: (1) a free and continuous access of air; (2) a constant supply of combustible material, and (3) the necessity for the continuous removal of the products of the combustion, for Willis clearly identified the burning of a flame in air and respiration in a living animal body; it is certain that he believed that they were chemically the same thing. It was in 1660 that the Hon. Robert Boyle, who did so much for the early mathematico-physical study of the atmosphere and of gases, performed the fundamental experiment as regards ventilation, namely, to exhaust the air around a living animal. He showed that long before the vacuum was perfect, a sparrow and a mouse had both died, and the flame of a candle had gone out. Boyle also understood that there was something besides watery vapor that rendered expired air unfit for further breathing by animals. G. A. Borelli about twenty years later was the first to estimate what we now know as the "tidal air," that is the quantity of air taken in and sent out at each breath, a most important datum as regards the supply of fresh air per person.

The Cornishman, Richard Lower, clearly perceived before 1669 that the blood in the lungs was arterialized by absorbing something from the inspired air, what we now know to be oxygen. Lower was also quite certain that the expired air was noxious and ought to be removed; were there no need for this change, he writes, "we should breathe as well in the most filthy prisons as amongst the most delightful pastures." Lower held it as an axiom that where a fire burns readily, there an animal can breathe easily. The full significance of Lower's conclusions was not grasped by his contemporaries; even so great a physiologist as Haller failed to see all that they involved.

The next step was taken also by an Englishman, an Oxford man of science, John Mayow. Working between 1668 and 1674, Mayow virtually discovered oxygen in a physiological sense. He named it "nitro-aerial particles," for he identified the substance which, absorbed from the air in breathing, produces animal heat, with the substance niter that appeared to be the cause of the combustion of gunpowder. Mayow died in 1679; and in England nothing was done as regards respiration or ventilation until Hales arose to rediscover much that Lower and Mayow had known well. In some respects Hales was less of a chemist than Mayow, but he caused hygiene to advance to a vastly greater ex-

tent because he applied what little theoretical knowledge he had to the solving of problems of very definite practical utility. He knew something of the work of his predecessors Borelli, Lower and Mayow. He knew that of his contemporary Boerhaave; but, much less technically learned than all of these, he became the pioneer sanitarian of the first half of the eighteenth century. He was not a physiological chemist like Lower and Mayow, but he was the discoverer of a method of sustaining respiration in the absolutely irrespirable atmospheres of coal-mines or burning houses. He suggested that the apparatus might be serviceable for divers. He was the father of all such as descend into "fire-damp" and "choke-damp" and "black damp" provided with an independent supply of air in an apparatus capable of absorbing the exhaled carbon dioxide. He was the Jubal of all such as handle rescue-apparatus. He was a pioneer in a great deal else that does not concern us now, for he was the first person in this or any other country to obtain by experiment on the living animal a demonstration of the magnitude of the pressure of the blood in arteries; and he is the father of vegetable physiology in England, and he is much else. But we must not imagine that, although Hales devised an artificial respiration apparatus, he was acquainted with all the properties of carbon dioxide. For just as Van Helmont in the seventeenth century worked with the carbon dioxide of combustion without being aware of all its properties, so Hales in the eighteenth worked with the carbon dioxide of respiration without realizing all that was involved in his researches. This sort of thing has happened again and again in science. Respiratory carbon dioxide was discovered by Professor Joseph Black at the University of Glasgow in 1754. In point of time nitrogen was the next constituent of the atmosphere to be identified: this was also by a Scotsman, Professor Daniel Rutherford (1749–1819) of the Chair of Botany at Edinburgh. The year of this was 1772, the man the maternal uncle of Sir Walter Scott. Within two years more, oxygen was separated by Joseph Priestley from mercuric oxide under the name of "dephlogisticated air." By 1775 Priestley had found that this gas supported both combustion and respiration. Had it not been for the phlogiston theory, to which he clung with fatal tenacity, Priestley would have been the undisputed discoverer of the gaseous basis of life; as a matter of fact, Lavoisier, as we are all aware, was the man who knew what he had got when by the end of 1774 he had isolated *oxygen* and so named it.

But we must not forget that Priestley also worked much on the properties of carbon dioxide, it was the gas he first studied near a brewery at Warrington. As early as 1772 he read a paper to the Royal Society showing experimentally that, while animal life could not be supported by this gas, plants, on the other hand, restored the wholesomeness to air rendered putrid by animal breathing. He also demonstrated that by both combustion and respiration the air loses one

fifth of its volume: for these researches Priestley received the Copley medal in 1773.

The details of the private life of Stephen Hales are neither numerous nor romantic. The son of Thomas, eldest son of Sir Robert Hales of Beckesbourn, Stephen was born in 1677 near the pleasant village of Beckesbourn in Kent, not far from Canterbury. His mother was Mary, daughter and heiress of Richard Wood, of Abbot's Langley. At the age of nineteen he went to Cambridge, being entered at Bene't College (now Corpus Christi), of which he became a fellow in 1703. In due time he graduated M.A. and he took his B.D. degree in 1711. His early scientific leanings may be inferred from his having studied anatomy, chemistry and botany as a recreation. Accompanied by William Stukeley, a fellow student, later M.D. and F.R.S., Hales is reported to have studied field botany on the Gog-Magog Hills and on Cherry Hunt Moor by the aid of Ray's catalogue of local plants, and also at this time to have made collections of fossils and of butterflies. It was as a student, too, that he contrived to make a cast in lead of the lungs of a dog. He did not neglect astronomy, for according to one account he constructed a "planetarium in brass" or, as it was later called, an "Orrery" on Newtonian principles. Having taken Holy Orders, Hales was presented in 1710 to the "perpetual curacy" of Teddington in Middlesex. Not long after he resigned his fellowship on being presented to the living of Porlock in Somerset; this he finally exchanged for that of Farringdon in Hampshire. The date of his marriage is uncertain: it is thought to have been in 1719; his wife died childless in 1721; Hales did not marry again. It was at Teddington that by far the greater number of his experiments were carried out. At his own expense he rebuilt the tower of the parish church of St. Mary's-in-the-Meadows. In 1718, at the comparatively early age of forty, Hales was elected into the Royal Society, and twenty-two years later was awarded the Copley medal—the highest honor in the gift of that learned body. Until within a year or two of his death he communicated the results of his manifold researches in the form of papers to the Royal Society. He published, however, in book form several treatises: his "Vegetable Statics" saw the light in 1726, and the "Hæmostatics" or Volume II. in 1733. Volume I. is dedicated to "His Royal Highness George Prince of Wales" and Volume II. "To the King's Most Excellent Majesty." This "George, Prince of Wales," and the "King's Most Excellent Majesty" are the same person, for in 1726 George I. was still reigning, but by 1733 his son George, who had been Prince of Wales, was now George II.

Although, then, Hales wrote extensively on vegetable and animal physiology, chemistry and medicine—for he discoursed on the alleged virtues of tar-water and investigated solvents for stone in the bladder—it is as a pioneer sanitarian that he must ever live in our grateful

remembrance. He did not occupy his time in calculations as to the number of cubic feet of air required per person per hour, but he designed a workable apparatus on the principle of the bellows for the purpose of abstracting air from places particularly badly situated as regards the changing of their air. The earlier forms were worked by hand, the later were driven by a windmill, their general design being much the same as that of bellows for church-organs. The velocity of outflow of air from the bellows, Hales expresses as 6¼ miles an hour, a little over 9 feet per second.

His first paper on the importance of ventilators in mines, hospitals, prisons and ships was read to the Royal Society in 1741, in which year an almost identical invention was announced by one Martin Friewald, "captain of mechanics" to the King of Sweden. So useful was this latter apparatus that the French government ordered an installation of it on all the ships of their navy. Not once or twice in the story of invention have important discoveries been made simultaneously and often in countries widely distant, as in the present instance. The title-page of the treatise in which Hales describes his invention reads thus:

> **A description of Ventilators whereby great quantities of fresh air may with ease be conveyed into mines, gaols, hospitals, workhouses and ships in exchange for their noxious air, and in preserving all sorts of grain dry, sweet and free from being destroyed by weevils both in granaries and ships . . . as also in drying corn, malt, hops, gunpowder &c and for many other useful purposes which was read before the Royal Society in May 1741.**

Truly it was not an age of succinct titles, but its length enables us to see that Hales had a clear idea of that one thing needful, namely, fresh in place of noxious air; he was under no doubt whatever that the air of mines, gaols, hospitals, workhouses and ships, left to itself, becomes noxious and must be changed. This is corroborated by the quotation from Milton which follows:

> **and God made**
> **The firmament expanse of liquid, pure**
> **transparent, elemental air.**

In this work he speaks of "the rancid vapors from human bodies"; from this it is not quite clear whether or not Hales was distinguishing respiratory carbon dioxide from the noxious vapors arising from the skin and lungs. We must at any rate remember, as has been already said, that he wrote without knowing of the discovery of respiratory carbon dioxide. It is certainly interesting to be told the very latest opinion as to the deleterious nature of breathed air is that it is not due to the carbon dioxide *per se,* but that the headache and distress are due to the moisture, the heat and the disagreeable, volatile, organic effluvia from the skin and lungs of the persons within the confined space. Without any technical chemical knowledge of the precise cause of impure air, Hales had grasped the far more important fact that

breathed air must be got rid of and sent outside into the ocean of the atmosphere.

It can not in fairness be alleged that those in authority were slow to avail themselves of the benefits of Hales's ventilators; but their adoption in the prisons, where the ventilation was excessively bad, was no doubt hastened by the deaths of the Lord Mayor of London, two Judges and an Alderman, all of whom became infected with gaol fever caught at the Old Bailey Sessions. "The Royal Society," wrote the late Sir William Huggins, "was called upon for advice and assistance. A committee was appointed to investigate the wretched state of ventilation in gaols. A ventilator invented by one of the committee was erected in Newgate, reducing at once the number of deaths from eight a week to about two a month. Of the eleven workman employed to put up the ventilator, seven caught the fever and died." There is not the slightest doubt that in those days to be sent to prison was the same thing as undergoing the death sentence of poisoning by foul air. Though Huggins does not mention Hales, it is certain he is the person alluded to as on the committee who introduced his ventilators into the prison. The version given by Peter Collinson in his sketch of the life of Hales (*Annual Register* for 1764) differs a little in one or two particulars: this writer states that in 1749 Hales's ventilators were installed in the Savoy prison by order of Mr. Henry Fox, later the first Lord Holland. Between the years 1749 and 1752 four prisoners died there of gaol fever as compared with between fifty and a hundred per annum previously. In the year 1750, out of two hundred and forty prisoners, only four died; and of these two died of smallpox and one of alcoholism, so that the salutary effects of Hales's installation were immediate and striking. In 1752 his ventilators actuated by a windmill and having ducts leading from twenty-four cells or wards were introduced into Newgate prison: as a result of this, Collinson says, the ratio of deaths after to those before the ventilation was as seven to sixteen, that is they had been reduced to less than 50 per cent. In 1753 Hales wrote an article in the *Gentleman's Magazine* on the applicability of his ventilators to army hospitals and to private houses. He also reported on their means in a smallpox hospital. Before his death his ventilators had been installed in the prisons at Winchester and Durham. In modern terminology, Hales ventilated by abstraction of foul rather than by propulsion of fresh air.

Hales's invention was greatly appreciated on board ship. Ships at this time were floating strongholds of death; between scurvy and ship fever due to poisoning by bad air, only the most robust men survived for any length of time. In 1755, Hales wrote a short but most interesting paper to the Royal Society, entitled "An account of the great benefits of ventilators in many instances in preserving the health and lives of people in slave and other transport ships." In this, Hales

speaks of "finding means to procure them fresh, salutary air instead of the noxious, putrid, close, confined, pestilential air which has destroyed millions of mankind in ships." He says "the principal cause of the sickness in ships is the noxious, putrid air; the obvious remedy is the exchanging that foul air for fresh by effectual means which are seldom discovered by dwelling only on objections." Hales further alludes to the "vulgar, false and groundless notion that they take up too much room . . . the men are eager to work them."

"Decay," he continues, "is wholly owing to damp, close, confined, putrid, corroding air, so the only remedy for this evil is the frequently changing the air among the timbers by plentiful ventilations." Hales published in this paper a letter dated London, September 25, 1749, from a Captain Thomson of the frigate *Success* which is most interesting reading:

> Our rule for ventilating was half an hour every four hours, but when the ventilating was sometimes neglected for eight hours together, then we could perceive, especially in hot weather, a very sensible difference by the neglect of it. All agreed the ventilators were of great service. The men did not need to be urged to work them. Two hundred men aboard for a year, pressed men from gaols, with distemper all landed well in Georgia. This is what I believe but few transports or any other ships can brag of, nor did I ever meet the like good luck before, which, next to Providence, I impute to the benefit received by the ventilators. . . . This certainly occasioned all kind of grain provisions to keep better and longer from weevels than otherwise they would have done, and other kinds of provisions received benefit from the coolness and freshness in the air of the ship which was caused by ventilation.

Hales then quotes a Mr. Cramond, who attributed the good health of his ship with three hundred and ninety-two slaves and Europeans, to the presence of the ventilators; twelve of the slaves died, but when taken on board they were all "ill of a flux." The next report is from a Captain Ellis, writing from Bristol, December 26, 1753. After lamenting the *vis inertiæ* of prejudice and ignorance, Ellis says:

> "It does honour to those noble and other worthy personages that join you in acts of such extensive humanity as the introduction of ventilators to hospitals, prisons, ships of war and transport &c as they necessarily render the miseries of the first more supportable, and the close and constant confinement of the others less prejudicial and fatal to their health and life.
>
> The ventilators were of singular service to us, they kept the inside of the ship cool, sweet, dry and healthy. The number of slaves I buried was only six, and not one white man of our crew (which was thirty-four) during a voyage of fifteen months, an instance very uncommon. The three hundred and forty negroes were very sensible of the benefits of a constant ventilation, and were always displeased when it was omitted."

Captain Ellis did better still in his next voyage in 1755, for not one of the three hundred and twelve slaves died, and these and all his crew to the number of thirty-six were landed alive and well at Bristol. Hales goes on to say that the Earl of Halifax (1716–1771)

told him of the great benefit derived from ventilators installed in transport-ships to Nova Scotia; the deaths in ventilated to those in non-ventilated ships being as one to twelve. Through soliciting the interest of the French man of science du Hamel de Monceau, Hales contrived to have his ventilators installed in certain prisons in France where English prisoners were confined. He jokingly said that he hoped that he would not be accused of assisting the enemy. The reverend sanitarian closes his paper with these words:

> They little consider that it is the high degree of putrefaction (that most subtle dissolvent in nature) which a foul air acquires in long stagnating which gives it that pestilential quality which is called the gaol-distemper, and a very small quantity or even vapour of this highly attenuated venom like the infection or inoculation for smallpox soon spreads its deadly infection. Ought not men therefore . . . to use their utmost endeavours to shun this pestilential destroyer by which millions of mankind have perished in ships.

Now this is a somewhat remarkable paragraph to have been written in 1755. It undoubtedly refers to typhus fever, known under all the following names: putrid fever, pestilential fever, ship fever, emigrant fever, hospital fever, and gaol fever. It was, for it is happily now quickly disappearing, the fever of bad sanitation, the scourge of unwashed, ill-fed, badly housed, neglected specimens of humanity. Even now its precise cause, whether coccus, bacillus or other parasite, is not known. The very latest suggestion is that it is an ultra-microscopical virus transmitted by some insect that infests persons of unclean skins. But the very fact that to-day we have not isolated the virus is a sufficient proof of its excessively elusive nature—a very attenuated poison indeed, as Hales says. Of course Hales did not know it as typhus fever: typhus, typhoid and relapsing fever were all confused until Sir William Jenner about 1850 clearly distinguished between the first two. With the rise of bacteriology, the microorganic origins of the last two have been established; the true cause of typhus has still to be discovered. While pathologists are still struggling over the precise cause of this fever, the practical sanitarians have almost banished it from Great Britain. Better feeding, more facilities for personal cleanliness, and above all a clearer appreciation of what ventilation means have cooperated in abolishing this horrid scourge; but let us never forget that the initial, intelligent stages of the war against it were undertaken by Stephen Hales.

Amongst other analyses Hales made was the analysis of the expired air. He evidently regarded death in explosions in mines and of the animals in the "grotto di cani" as being due to the same poisonous gas.

Besides attacking and solving the problem of ventilating such places as most urgently needed it, Hales devised a method whereby a person could enter an irrespirable atmosphere and continue to breathe,

if not absolutely pure air, such air as could sustain life for some minutes, long enough to enter a burning house or, as he suggested, a laboratory filled with noxious fumes. The mechanism was a bladder divided up into compartments by four diaphragms of flannel or linen soaked in a solution of potash or "sal tartar" capable, as we now know, of absorbing the respiratory carbon dioxide. A tube led from the far end of the bladder and, curving upwards, terminated in a mouthpiece near which were placed two valves, one allowing air to enter the near end of the bladder, the other preventing it from passing back into the far end. The nostrils had to be closed, as they have to be in all mouth-breathing forms of such apparatus. The receiver held between four and five "quarts of air"; Hales thought that with one gallon of air and four diaphragms, respiration could be supported for at least five minutes. He remarks, what we can readily believe, that there was much discomfort unless the valves worked easily.[1]

In view of the prominence which life-saving apparatus has attained at the present day, it seems exceedingly interesting to know that before 1726, a practical attempt had been made to construct an artificial rescue-apparatus. Hales himself contemplated its use not only in the foul air of mines, but by divers under water; it is, however, very doubtful whether the mechanism as he left it could have been used under water. This simple invention is the humble parent of the various ingenious life-saving apparatuses of the present day, the Fleuss, the Dräger, and others which enable a man to remain for upwards of two hours in atmospheres not merely poisonous, but actually deadly. As we have already seen, it was this invention of Hales that inspired Black to discover respiratory carbon dioxide.

As all men of science know, Stephen Hales may be said to have founded the science of experimental, botanical physiology; his observations by means of mercury manometers on the pressure exerted by the rising of sap in vines are classical. Although he was a pioneer, he fully acknowledged the work done in plant physiology by Mayow, Grew and Malpighi. His views regarding the transpiration of plants and their nourishment, and how they utilized some constituent of the atmosphere only under the influence of solar light, were all in advance of his time.

In animal physiology he was also a pioneer, for he was the first to ascertain the magnitude of the pressure of the circulating blood: this he did by opening the left crural artery of a living animal, the horse. His method was crude: he merely allowed the blood to rise as high as it could (8 ft. 3 in.) in a vertical tube partly of brass and partly of glass; but the principle of his method is even now most fruitfully used in practical medicine. He studied the general physiology of the blood-pressure in arteries and in veins, as also the force and output of the

[1] Cf. "Vegetable Statics," Vol. I., p. 265.

left ventricle, acknowledging, however, previous work by Harvey, Lower, Borelli, Pitcairne, Keill and others. As became every physiologist of his time, he wrote on the "animal spirits" and on the "sympathy" between the nerves; he studied experimentally the physics of respiration; he produced pneumo-thorax in the dog, and speculated on the sources of animal heat, agreeing with Boerhaave and the iatro-physical school in attributing it to friction of the blood and blood-cells against the walls of the vessels. He tried to explain the florid nature of arterial blood, but on this point he was not so enlightened as his predecessor Lower about sixty years before. He used the microscope in an interesting way to try to gain information as to the cause of muscular contraction in the living frog. He incidentally saw the red blood corpuscles in the living capillaries and noticed that the diameter of the smallest vessel was equal to that of the blood-disc. He gives the receipt of an injection-fluid for blood-vessels. He continued Harvey's work, by studying the rupturing pressures in blood-vessels and the rupturing strain of various animal fibers. He speculated on the physiology of renal secretion.

In what would now be regarded as pure medicine and even surgery, Hales was just as active. He wrote critically on the therapeutic value of "tar-water"; he wrote on fevers and on the possible effects of fever heat on the blood, actually suggesting that the shivering fit of ague might be due to the too thick blood not passing with ease through the capillaries. He studied the effect of alcohol on the living organism by injecting brandy into the blood-vessels of the dog. He wrote on paracentesis abdominis. Hales spent a great deal of time in attempts to discover satisfactory solvents for stone in the bladder and the kidneys, and actually devised a method of extracting stone from the bladder.

In the physical sciences he wrote on earthquakes, and he invented an instrument for determining the depths of the ocean: this appears to have been of some practical service, but, according to one account, was lost in the West Indies. Hales invented a method for the dredging of harbors. He gives directions for "salting" meat for long voyages.

Hales, as we have seen, was patronized by Frederick, Prince of Wales, the eldest son of George II., who died before his father in 1751. His widow Augusta, daughter of Frederick, Duke of Saxe-Gotha, for the last ten years of Hales's life the Princess Dowager of Wales, had a great regard for the Reverend Doctor, and there is no doubt that had he so desired it, he might have become a bishop. The utmost he would allow, refusing a canonery of Windsor, was to be made "Clerk of the Closet" or almoner "to the Princess Dowager." After his death, the Princess erected a mural monument in marble to his memory in Westminster Abbey. He is not buried there amongst England's other great ones, but under the tower of his old church at Teddington. The memorial is wrought in *alto relievo;* it represents the figures of Religion

and Botany supporting a medallion of the philosopher beneath which is a globe with the winds portrayed on it in allusion to Hales's invention of ventilators. The laudatory inscription is in Latin verse, a translation of which I am enabled to give through the kindness of Professor Wallace Lindsay, LL.D., of the chair of Latin at the University of St. Andrews.

> To the Reverend Doctor Stephen Hales,
> Augusta, mother of good George III,
> Erected this monument.
> She selected him for her chaplin.
> He died, January 4th, 1761.

> At Hales' tomb which Augusta caused to rise with gleaming stone and to have due beauty, Piety and grey haired Faith and supreme Virtue, a sacred band, drop constant tears; while above the dead prophet divine Wisdom proclaims, "He was skilled in helping men's troubles, he too in tracing God's works. No lapse of time will weaken your praise, great Hales, or your titles! England is proud to enroll you amongst her noblest sons, England who can boast a Newton"!

This is interesting as being almost a contemporary estimate of Hales. His medical work and researches as a sanitarian are evidently alluded to in the phrase "helping men's troubles"; his more purely scientific work being alluded to in "tracing God's works." Sir James Edward Smith, the physician and naturalist, said "his philosophy was full of piety."

Seeing that the stone over the grave of Hales has done duty as one of the flag-stones of the porch of the old church of St. Mary's, Teddington, for more than 150 years, it is not surprising to find that its inscription is now almost entirely worn away. In January, 1911, a number of English botanists unveiled a tablet on the wall of the porch of the tower which they caused to be inscribed as follows:

> Beneath is the grave of Stephen Hales. The epitaph now partly obliterated but recovered from a record of 1795 is here inscribed by the piety of certain botanists A.D. 1911. "Here is interred the body of Stephen Hales, D.D. clerk of the closet to the Princess of Wales, who was minister of this parish 51 years. He died 14th of January, 1761, in the 84th year of his age."

One of the few redeeming features in the character of Frederick, Prince of Wales, was his friendship for Hales. It is not very far from where the Prince lived at Kew to where Hales worked at Teddington, and so H. R. H. would frequently drop in and watch the scientific clergyman surrounded by his pressure-gauges, bellows and crucibles.

Another, and much more distinguished neighbor of Hales, was the poet Pope with whom he seems to have been pretty intimate. Certain it is that the Reverend Doctor was one of the three witnesses to the will of the wicked wasp of Twickenham dated December 12, 1743.

Pope alludes to Hales as "plain Parson Hale" in the second of the moral essays (the poem is "Epistle II. To a lady: of the characters of women"). The lines are:

> **Alas! I copy, or my draught would fail,**
> **From honest Mahomet or plain Parson Hale.**

I confess I don't know what this means, but one can see a very unwarrantable liberty taken with Hales's name. The poet's own note on this is:

> **Dr. Stephen Hale not more estimable for his useful discoveries as a natural philosopher than for his exemplary life and pastoral charity as a parish priest.**

Pope, however, has left it on record that he highly disapproved of the doctor's vivisectional experiments. Peg Woffington, the actress, was for a time a parishioner of Hales.

We strongly suspect that the theology of Hales was ponderous and his religious discourses dull. Absolutely correct as regards the sex morality of his own life, he appears to have dealt pretty severely with any erring members of his flock, for there is extant a list of names of women whom he made do public penance in church in a manner more resembling the custom amongst the strictest of the Scottish Covenanters than that of English Episcopalians.

At least one sermon that Hales delivered has come down to us, because it was published as the anniversary sermon preached before the Royal College of Physicians in the church of St. Mary-le-Bow on September 21, 1751. It is now a rare pamphlet, entitled "'The wisdom and goodness of God in the formation of man,' preached according to the institution of Dr. Crowne and his widow, the Lady Sadler, by Stephen Hales, D.D., F.R.S., Clerk of the Closet to Her Royal Highness the Princess of Wales." It is so full of curious anatomical and physiological allusions that it reads far more like a lecture in natural history than what we should consider a sermon. Another sermon preached by Hales in 1734 has come down to us. His text was Gal. VI., v. 2, the audience the trustees of the colony of Georgia, for Hales was one of the trustees of this newly founded colony (1733).

Another of Hales's neighbors was the dilettante, Horace Walpole, who lived near by at Strawberry Hill; he wrote cynically of Hales as a "poor, good, primitive creature." A far better judge, the physiologist Haller, declared that Hales was "pious, modest, indefatigable and born for the discovery of truth."

Hales must have been modest, for there are very few references to him in contemporary literature. He is not once mentioned in the chapter on Science in Ashton's "Social life in the reign of Queen Anne." By his scientific peers, however, his worth was fully recognized. In 1726 the University of Oxford conferred on him the degree of D.D. The Royal Academy of Sciences at Paris in 1753 elected Hales one of the eight foreign members in the room of Sir Hans Sloane, Bart: deceased.

The botanist, John Ellis, named a genus of plants, *Halesia*, in honor of him.

Hales's portrait was painted by Thomas Hudson (1701–1779), an English artist who had the honor to have Reynolds for a pupil. The monument in the Abbey is by Wilton who executed Wolfe's in the same sanctuary.

One of the most scholarly accounts of Hales is from the pen of Professor Percy M. Dawson, M.D.

To arrive at any definite ideas as regards Hales's views on his own times or on the society of his day is very difficult, since almost all that we know of him is in an exclusively scientific environment. Seeing that his patrons were the Prince and Princess of Wales and that he was quite intimate with the Duke of Cumberland, he could hardly have been other than an ardent Hanoverian. From all that we have to judge by, Hales's personal tastes harmonized with the Georgian Philistinism around him, for he is reported to have removed a beautiful east window in the church at Teddington, substituting for it something of greatly inferior beauty.

Hales lived through a period that was by no means destitute of incident; it included the Handel-Buononcini controversy, the Jacobite Rising, the quarrels of George II. with his eldest son, the battles of Dettingen and Fontenoy, the failure of the great attack on Carthagena (1741), the development of Britain's resources under the peaceful administration of Sir Robert Walpole, the commencement of the vigorous rule of William Pitt the elder, Wolfe's magnificent achievement on the Heights of Abraham, Clive's crushing of Surajah-Dowlah at Plassey, the reform of the calendar and the preaching of Wesley.

Pope, Gay, Young, Thomson, Cowper, Johnson, Gray and Collins in literature; Hogarth, Gainsborough and Sir Joshua in art, Handel in music, and Sir Hans Sloane in science are the names of honorable mention during the life-time of the Rev. Dr. Hales.

While we congratulate ourselves on having attained to an understanding of the principles of ventilation, on having abolished typhus fever from our hospitals, prisons and ships, on having devised apparatus for sustaining life in irrespirable and deadly atmospheres, let us never forget that the initial stages in the comprehension of these things were worked out not by any high-placed, well-paid, public official, but by a modest amateur, the scientifically minded, country clergyman, Stephen Hales.

THE PLACE OF DESCRIPTION, DEFINITION AND CLASSIFICATION IN PHILOSOPHICAL BIOLOGY

By Professor WM. E. RITTER
SCRIPPS INSTITUTION FOR BIOLOGICAL RESEARCH

Empirical theory of knowledge tends to regard detailed, complete description as identical with explanation. (Professor R. Adamson.)

. . . it would hardly be too much to define logic as the theory of classification. (W. S. Jevons.)

Science can extend only so far as the power of accurate classification extends. If we can not detect resemblances and assign their exact character and amount, we can not have that generalized knowledge which constitutes science. (W. S. Jevons.)

. . . the mathematical and mathematico-physical sciences have, in a great degree, determined men's views of the general nature and form of scientific truth; while natural history has not yet had time or opportunity to exert its due influence upon the current habits of philosophizing. (Wm. Whewell.)

I WISH to point out in the briefest way possible the vital importance to biology of the truth of these statements.

We are familiar with the view that the transition from the pre-Darwinian to the Darwinian era of biology was accompanied by a complete revolution of conception as to the significance and value of our systems of classification of living beings. The current notion is that the old taxonomy was superficial in that it was merely descriptive, but that, with the oncoming of the doctrine of evolution, it became profound because it then became a record of evolution. While formerly we are wont to say, the schemes of classification were only logical, or verbal, those of the present era are truly scientific, because natural; and they are natural because based on genetic kindred. And in the minds of many biologists the still further notion has gained lodgment that systematic zoology and botany should be looked upon as marking the juvenile period in the life of biology; and as having been outgrown and left behind when evolution came, something as a boy's falsetto voice and beardless face are left behind when puberty is reached. It is this view, I suppose, which makes many a present-day biologist feel that if by chance he is caught having anything to do with description and classification, he must explain that it is only a little by-play with him, that he is not really interested in it, it being too small a matter to merit the full occupancy of his manly powers.

I want to show three things: first, exactly what has happened to taxonomy as biology has progressed; second, something of the monstrousness of the fallacy into which biologists have fallen in conceiving taxon-

omy as an outgrown stage in the development of biology; and third, something of the wretched consequences that have resulted from the fall.

A quotation from Huxley's "Life of Owen" may serve as a starting point of the discussion:

> The classifications of the scientific taxonomist are of two kinds. Those of the one sort are merely handy reference catalogues. . . . The others, known as *natural* classifications, are arrangements of objects according to the sum total of their likenesses, in respect of certain characters. . . . And natural classification is of perennial importance, because the construction of it is the same thing as the accurate generalization of the facts of form, or the establishment of the empirical laws of the correlation of structure.

That which makes taxonomic biology as practised by many systematists genuinely superficial, and has so depreciated its value in the minds of many biologists, is failure to distinguish sharply and see the profound significance of the difference between the two sorts of classification referred to by Huxley. The sort of classification which he calls "merely handy reference catalogues," I call *synoptic classification,* and remind the reader that such classification rests upon *synoptic description.* The other sort of classification, said by Huxley to be of "perennial importance, because the construction of it is the same thing as the accurate generalization of the facts of form," I call *analytic classification,* and ask the reader to note that it rests on *analytic description,* just as synoptic classification rests on synoptic description. And here I must state that analytic description and classification will include considerably more, as I use them, than was included by Huxley in his second sort of classification.

In order to bring into clearer view the close kindred between the biological and the logical aspects of our subject, we shall so choose our language as to fix attention quite as much on the *meaning of the names* used, as on the natural objects to which the names are applied.

If any one is disposed to shy at the proposal to thus connect biology with logic, he may be reminded of a dictum of one of the most famous and also the most objective of biologists—Cuvier. "In order to name well, you must know well," said the father of comparative anatomy. The import of this straightforward statement is that natural science deals with natural objects and that the names of these objects are the instruments by which the work is done. As a speculator, Cuvier did not escape the common weakness of the class, that of permitting Ideas to so intrude themselves between object and name as to prevent assurance that the two should really fit each other; but, as naturalist he stood firmly for the practise of making both knowing and naming apply very directly to the object. So far he was on the road to the sound position later definitely taken by J. S. Mill as a logician, that common sense is right in calling the word which stands for an object the name of the object, and not merely the name of our idea of the object.

in common in that biology can do nothing with the natural objects which are its subject matter except through the instrumentality of a great lot of names; while logic can do nothing really significant with names of ideas concerning living beings unless those ideas have their exact counterparts in the objects themselves.

To be explicit, we shall deal with the description, definition and classification of *man;* but instead of doing this in the usual terminology of the systematist, we shall talk about the meaning of the word "man."

Imagine a normal child born on an oceanic island, the only animal inhabitants of which are its mother and itself; and imagine further that the mother, an educated woman, has taught her child all sorts of things, except about other human beings or other animals. Not the smallest fragment of information has she imparted to the child about its own kind, other than its mother. What would be the character of the child's knowledge of the humankind? Does any one question that it would be considerable, definite and real? Would not the child know its mother's form and countenance and voice, and many other things about her, just as well as though it knew innumerable other people? Unquestionably. It would have a descriptive, but no definitive knowledge of man, except in so far as the knowledge of itself would be differentiated from its knowledge of its mother.

Authorities on logic make a good deal of the point that "the concrete individual object can be described, but not defined." And they say, furthermore, that description is synonymous with "accidental definition," this latter being again defined as assigning the "accidents" of an individual. But since the "accidents" of an object have been, according to much historical logic, set over against its "essence," "accidents" have usually been treated by logic as a sort of Cinderella, the homely, despised sister, in the family of so-called Predicables.

I find justification for going thus much into logical doctrine in the fact that recent biology has shown a strong tendency to follow formal logic in exalting essence and despising accidents.

The practical point to be brought out is this: no matter how insignificant, or obscure, or transitory, may be a certain attribute of an object, in so far as that attribute is positively and repeatedly observed, it furnishes just as trustworthy a piece of knowledge about that object, as any attribute whatever can furnish.

Suppose the mother of our hypothetical island child had a mole on her chin; or that the sunshine brought out freckles on her nose which disappeared again during the winter. These marks would be accidents, according to logic; and biologically regarded would be quite insignificant. But they would be as indubitable elements in the child's knowledge of its mother as any other elements that can be mentioned.

Let me ask any reader who is "keen" enough on the different kinds of automobiles to be able to distinguish most of the "makes" as they are passed on the road, what marks he relies on for identifying each type of car? Is it not true that in most cases you depend upon one or a few very trivial things? Color comes in; but, on the whole, one finds himself giving less attention for identification purposes to this conspicuous attribute than to others far less conspicuous. Just now the shape and color, not the name, of the manufacturer's plate placed on the radiator of so many machines, is a good identification mark for machines coming toward one. For the rear view of a machine with the top up, the number and shape of the window panes in the back curtain are useful marks.

The purely logical points deserving emphasis in this familiar but typical case are: first, the trustworthiness of the identification marks in spite of their triviality. The number and shape of the windows in the back curtain are just as positive and real as traits, that is, they are, logically regarded, just as important attributes of a particular class of machines as the number and shape of the cylinders; and second, the fact that using the marks in the way we do is purely descriptive, so far as concerns the recognition of an individual machine, but is definitive in so far as that machine is differentiated from any other kind of machine. Had there never been more than one automobile made, so that then there could be no question of distinguishing it from others of its kind, the windows would still be no less positive and real, though they would not, manifestly, then furnish distinguishing traits within the general class automobiles. But here there comes to view a difference of the utmost importance between the way attributes are definitive of man-made objects like automobiles, and natural living objects like men. In the first class of objects we are perfectly sure that many, usually most, of the attributes which the old logic would call accidents had no genuinely dependent relation to most of the other attributes of the object; while in living beings, especially of the higher classes, we are now certain that the great majority, if not all, the attributes, even those which formal logic would call accidents, are in vital relation with many, usually very many, other attributes. Thus recurring to the shapes of back curtain windows in automobiles and freckles on the nose of our hypothetical island mother, we know that the former have no fundamental relation to the more essential attributes of the machines, as, for example, the style of engine or carburetor or magneto; while on the other hand we know with equal certainty that freckles are vitally related to, indeed are wholly dependent upon, various other attributes, notably the complex attribute known as complexion, which again is vitally related to the blood system, and so on.

There are few, if any, points at which biology is more at sea than

in this very matter of the factual and logical, *i. e.*, the objective and subjective relation of the attributes or traits of organisms to one another and to the whole.

We now return to the problem of defining the word man. By the time any normal child is four or five years old he is in possession of the raw materials of a fairly comprehensive and entirely reliable description, a less extensive, but still unequivocal, definition, and the first of the essentials of a classification of man. He positively knows some of the attributes which distinguish a man from a house or a rock; some of those which distinguish him from a tree; probably some of those which distinguish him from a fly; probably, too, some of those which distinguish him from a chicken; and almost certainly some of those which distinguish him from a dog, a cat, a cow, and a horse. In a word, he has the raw material for the synoptic description and classification of man; that is, for the synoptic meaning of the word man.

Attention should here be called to the fact that the synoptic classification of man as elementary biological instruction presents it is apt to be slighted at its two ends. Too frequently, the beginning is made with:

Kingdom,	*Animal,* and runs on:
Province,	Metazoa.
Phylum,	Vertebrata.
Class,	Mammalia.
Order,	Primates.
Genus,	Homo . . . and ends with
Species,	*Sapiens.*

The point of criticism is that the super kingdom, the Empire (if our terminology must retain its ancient monarchic coloring), is not constantly enough included at the broad end; and at the narrow end the subspecies or variety is more frequently slighted than it ought to be; and from the very apex the individual is almost entirely ignored.

"*Empire,* Living Being, or Orgainsm, or Bios" ought to be always included as the logician's genus generalissimum; and, at the other end, "*Individual,* Eleanor, Ezra," etc., ought to be always included as the logician's species specialissima, or infirma species.

The synoptic description, definition and classification of man would then be: any natural body which is multicellular has a vertebral column, suckles its young, habitually walks erect on its hind limbs and uses its fore limbs for prehension, and talks rationally. And this is, too, both a biological and a logical meaning of the word man.

It is desirable to raise the question at this point as to the difference between the biological and the logical meaning of the term man. The kernel of the difference seems to me statable thus: The briefest possible biological meaning of the word spreads it out, as one might say, evenly over the whole living world, while the briefest possible

logical meaning does not do this. The insular mother whom we invoked in imagination may be supposed to teach her child formal logic, and, in so doing, to make use of herself and her child to illustrate the logician's use of the terms genus and species. She might say to the child:

> You and I are natural bodies like the rocks and the clouds; but since we talk with each other, a thing which neither rocks nor clouds can do, we are particular kinds of natural bodies. When bodies stand in such relation as this to one another, we, as logicians, speak of them as being in the relation of genus and species.

So far as I can see, this example, if supplemented by others of like import that might be drawn from inanimate nature, could be made to completely satisfy the needs of formal logic as touching its doctrines of naming, defining, dividing, classifying. In a word, formal logic is not obliged to take cognizance of the fact that living nature contains any organisms other than man himself. Logic is something that can be used upon living beings generally with great effect—something that can occupy itself very interestingly and profitably with such things, but it is not obliged to be so used.

Logic goes to nature to get illustrations of how thought works rather than to actually learn nature. Reverting to Jevons's statement that logic may be defined as the theory of classification, we may remark that, so far as external nature is concerned, while logic may be defined as the theory of classification, it can not be defined as the practise of classification. It is important to call attention to this distinction between logic and biology since even biologists frequently fail to recognize it and are beguiled into trying to impose the laws of thought upon nature by asserting that such and such a supposition about nature is a "logical necessity." Although logic is so important to the natural scientist as an instrument, quite as important is it never to forget that it is only an instrument. Logic is one of the many children of nature; it is not its parent or ruler.

A practical point to be noticed here is that right regard for logic in the business of the taxonomist clearly reveals both the unwarrantableness and misfortune of the view, so widely held, that synoptic descriptions and classifications are artificial or puerile, and devoid of scientific value. If such a definition of man as that just given does not express his nature—is not a natural definition—in what terms, pray, can he be naturally defined? The definition is natural, but meager. This and not its artificiality is its fault; and from this fault arises the need for the second kind of classification spoken of at the outset.

To this other sort of classification and the second meaning of the word man, we now turn. Logic lays great stress on the difference between extension and intension in the meaning of names. When the

word man is merely thought of as applying to the individuals of the human species, its meaning in extension is before us. When, on the other hand, thought goes to the attributes of man, to what makes him a man, rather than to individual men, it is occupied with the meaning in intension of the word.

Now, as to our point about the second, the analytic classification of man—the analytic meaning of the word man. Let us begin with the reminder that meaning in intension is concerned not with the mere naming of objects, but with the attributes of the objects named.

Let the reader recall that taxonomic research in both zoology and botany has for years, so far as it has been based on morphology exclusively, taken as one of its guiding principles *neglect nothing.* This means, stated in the terms of logic, that this aspect of taxonomy has incorporated into its purpose and method, the study of terms in their intension. This is really, I believe, what was in Huxley's mind, at least in the back-ground of it, when he asserted that the second kind of classification is the "same thing as the accurate generalization of the facts of form."

A prime object of this paper is to contend that biology has now reached a stage in its progress where we can no longer restrict our dictum "neglect nothing" to morphological attributes, but must extend it to all attributes of organisms whatever—morphological, physiological, ecological, chemical and all the rest. And it should be pointed out that the movement of biology in this direction was more or less distinctly seen by at least one biologist nearly a century ago, namely, G. R. Treviranus. "The doctrine of organization," he said, "is founded upon comparative anatomy, oı the systematic distribution of living bodies, and on organic chemistry."

I believe a comprehensive review of the whole range of biological results won during the last five and twenty years, let us say, will convince any one that each of the main provinces of research—comparative physiology, ecology, experimental behavior, genetics and biochemistry, no less than histology, cytology, embryology and regeneration, would furnish differentia for a classification of the organisms used in the researches; or at least that they contain differentia corresponding to the systems of classification previously established on the basis of pure morphology.

What does this signify for the attitude of biologists toward their problems, and for methods and enterprises of research?

It signifies many things, one of which particularly concerns us now, and may be put into the following general proposition: No biological phenomenon is adequately interpreted or dealt with experimentally, until it has been considered with reference to the place which the organisms to which it pertains hold in the system of classification. To illus-

trate, no generalization about the chromosomal structure and behavior in the spermatogenesis of species x of genus a can be accepted as fully valid until compared with the chromosomal structure and behavior of species M, N, O, P, etc., of the same genus. And a like restriction must be placed on generalization about the reaction of species x to light, or to any other stimulus, or to its distribution in nature, and so on.

To undertake the recital of special researches in support of this proposition would be to undertake the review of most of the recent investigations in the provinces of biology mentioned. And notice this: The results of these researches look in the direction indicated despite the fact that in most cases the studies had little or no systematic intention. The great amount of evidence of this purport is mostly incidental to other motives of investigation.

I would not be understood as advancing the hypothesis that every species of plants and animals differs from every other species to some extent in every attribute. What I affirm is that the inductive evidence has now gone so far toward proving every sharply differentiated species to contain some differentia in all the main provinces of their structure and function, that to assume the absence of such differentia in any given case, is unwarranted.

Although in the interests of practical biology it is desirable that a searching examination of the whole range of biological knowledge should be made from the taxonomist's standpoint, for a short theoretical discussion like that in which we are now engaged all that is incumbent upon us is to look, and that only cursorily, into a single province of biology, namely, biochemistry. This is all that is necessary, I say, because the analysis of all phenomena of life into chemistry and physics being the ultimate goal of biology according to the now dominant biological philosophy, if it turns out that the chemical analysis is exhaustive only when done on the basis of taxonomy, then it would seem to follow necessarily that all phenomena of structure and function intervening between the grosser morphological features with which taxonomy has for the most part busied itself, and the ultimate physicochemical features, must also be brought to a taxonomic basis before they are exhaustive.

It would be difficult to find a better example of weightiness of inductive evidence as dependent upon cumulation in particular lines, and convergence of different lines, than that presented by biochemistry bearing on the hypothesis here under consideration. Concerning the evidence of the chemical differentiation of species drawn from investigations on the blood of higher animals, recall the results of Reichart and Brown on the crystallization of hemoglobin. Here is one of their statements:

> own proper form and axial ratio when the blood of different individuals of the same species is examined. . . . But upon comparing the corresponding substances in different species of a genus, it is generally found that they differ one from the other to a greater or less degree; the differences being such that when complete crystallographic data are at hand the species can be distinguished by these differences in their hemoglobins.

Let us assume there is ground for questioning the full trustworthiness of this conclusion. Notice the strong presumption of its general reliability produced by its accordance with evidence from a wholly different kind of research on the serum of blood, namely, that on the precipitin reaction; and from still another kind, namely, that on the hemolytic action of one blood upon another. Nor should we fail to recognize the convergence of evidence for chemical specificity of organisms drawn from comparative investigation on milk; on the enzymes of digestion; and from such direct analyses of organic structure as those of the sperm of many species and genera of fishes. I mention only one other line of evidence of like purport clearly to be counted as chemical, though not usually so cited; namely, that of the odors and flavors of plants and animals. This is an exceedingly rich field of inquiry, even though difficult of cultivation by ordinary laboratory methods. The methods to be chiefly relied upon here are those of the senses of smell and taste, and it is interesting to reflect that there is available for utilization not merely these senses in man, but in animals as well. In the olfactory sense of the ant and the scent hunting dog, for example, we have a method of chemical discrimination—of qualitative chemical analysis if you please—which seems to surpass in delicacy anything laboratory manipulation can hope to attain.

Natural history and biochemistry are being inevitably drawn together by the very nature of their subject matter. Descriptive zoology and botany are becoming chemical in part, and bio-chemistry is becoming zoological and botanical in part. Organisms are indeed being "reduced to chemistry" in the familiar phrase; but the statement tells only half the story, unless it specifies the *particular* chemistry to which they are reduced. Each kind of organism has a chemistry to some extent unique. In one of its aspects biochemistry is becoming a subdivision, or branch, of systematic zoology and botany, just as anatomy has been for a long time. "Almost any group of tissues," said Minot, "would offer a favorable opportunity for the discussion of genetic classification." Seemingly the same may be said of biochemical substances.

Many biologists working in several provinces of the organic realm, particularly in those which, like cytology and biochemistry are concerned with the minute and difficultly observed structure and functions of organisms, appear to be laboring under the delusion that they are doing something totally different from description. They seem to think their work

analysis, or especially causal analysis, to it. As though the treatment of causal factors which are intrinsic in an organism were not part of the description of that organism, and as though causal factors extrinsic to the organism; that is, belonging to the organism's environment, were essentially a part of biology at all! I believe full and unbiased consideration will convince any one that the word analysis, occurring so frequently in recent biological writings, always means ***analytic description and classification,*** as these terms are elucidated above, if it has any objective meaning at all. It is undoubtedly true that as touching organisms themselves a vast amount of analysis has been practised upon them that is not descriptive; but this is because it is purely speculative—because it is subjective and not objective. Most of the analysis of the characters of adult organisms into "determinants," "determiners," "factors," etc., of the germ, is of this sort. And as touching the environments of organisms it is a remarkable thing once one comes to notice it duly that the results of innumerable researches have been published in biological journals during the last two or three decades, that were not in a strict sense biological. The studies were undertaken not so much to learn the nature of organisms as to test the properties of certain physical and chemical agents in respect to their influence on organisms. Incidentally, one might almost say, they have brought out many suggestive facts about how organisms may behave when placed under unusual and unnatural conditions. But they have not taught us so very much about the normal behavior of normal organisms under normal conditions. Indeed, a considerable number of biologists have been so bewildered by what they have seen and by their mode of speculating, that they have seriously questioned whether there is such a thing as a normal organism in a normal environment!

The sooner it is borne in upon the minds of all students of living beings, no matter with what aspects of such beings they may be occupied, that they are engaged in the great task of describing and classifying the living world; and, so far as "pure biology" is concerned, are doing nothing else, the sooner will objective biology get itself set off from subjective biology and the sooner will philosophical biology become purged of the many morbific growths which now impair its health and mar its beauty. Never more than in this present day when experimental research has gained so wide and lasting, and, on the whole, beneficent a hold in biology, has there been need of fidelity to description and classification. Never more than now, I say, because the practical work of experimentation on organisms does not promote observance of the classifier's watchword neglect nothing. Indeed, when the experimental method is raised, as some enthusiasts try to raise it, to the high place of an end in itself, the tendency is rather to neglect everything except

the one or a very few things which the experimenter must of necessity make the object of each special piece of work.

Although the practical biologist knows that his strivings after explanation are utterly futile unless always accompanied by description the spell of subjectivistic metaphysics is still so strong over science that not many biologists have yet grasped the fact that all true explanation is reached through description. Investigators rarely seem to notice that the explanations they propose are usually in reality hypotheses, and that the proof, or the greater or less probability of truth of these explanations (hypotheses) are wholly dependent upon the accuracy and fullness of description to which the organisms are subjected in the aspects of them to which the explanations pertain. Take the classic case of Goethe's explanation of the flower as a transformed branch with its leaves. Is it not true that just in so far as this explanation is accepted it is done on the basis of the accepted descriptions of flowers and branches and leaves? If a true explanation of cancer is ever reached does any one fail to recognize, when he thinks about the matter, that it must come in the form of well-verified description and classification of the whole complex of organic phenomena implicated in the disease?

A true though incomplete distinction between description in the ordinary sense and explanation in the ordinary sense is that the process of describing is very little guided by hypothesis, while explaining is very largely so guided.

Early in the paper, I promised to say something about the baneful effects that have flowed from the neglect by modern biology of the principles of description and classification. *Sine systeme chaos,* is the motto standing at the head of an elaborate, recently published work on the arrangement of the animal kingdom. This motto should be adopted, in substance at least, for any and every comprehensive biological treatise, no matter in what field; and I insist that failure to adopt it has thrown the speculative biology of our time into a literal state of chaos.

The revolt against the dry and formal nomenclatorialism into which biology had wandered in the period immediately preceding Darwin, has gone so far as practically to deny that many of the really best established, most important names in biology have any essential meaning at all. Witness, for example, the effort now taking shape with a few biologists, notably with J. S. Haldane, "to raise the term organism to the level of a category," as Henderson has characterized Haldane's undertaking. As a matter of fact, the effort is to restore, not to originally elevate the term, for a study of the history of biological theory clearly discloses that the term organism was long ago accepted as a category in the very best writings. For example, whenever the cell is interpreted as an "elementary *organism,*" as it has usually been since Brücke first

entity—of biology.

From the extreme devotion to description and classification which characterized the older biology, the new has gone, in several of its most important aspects, to the opposite extreme of scarcely any accurate description and classification at all. Very few biologists appear to have considered how this attitude toward systematization has affected philosophical biology, and especially the biology of man, and so the general theories of human life, and influence upon human conduct.

We approach here a matter of vast scope, one altogether too vast to be more than touched in a communication like this. But there is one segment of it which, though lying close to the field of biology proper and of great importance, appears to have attracted the attention of professional biologists but little.

I refer to that melange (the thing will not allow itself to be called a system) of utterances and more or less definite teachings about the human species that has got into men's minds during the last thirty or forty years, and has found its fullest expression in the writings of Friedrich Nietzsche.

Surely biologists have not taken as much note as they should of the insistence by philosophical anarchists and other disciples of Nietzsche that their prophet is the particular and supreme "philosopher of evolution."

Into the tumultuous whirlpool of discussion of the Nietzschean doctrines I have no wish to enter, at least in this place; but a few things about it I believe ought to receive consideration by biologists, especially by American biologists. Should the matter be thus attended to, I believe it will be seen that there is a great measure of truth in the claim for Nietzsche as the philosopher of evolution; evolution being conceived as it usually has been in the modern period; and the particular point I want to make is that he did his philosophizing, primarily about man and very secondarily about the rest of the living world, in all but total disregard of, seemingly in almost total ignorance of, the natural history aspect of biology. His appeals to physiology, or something he called physiology; and to some of the results and conceptions of physiological psychology (although I do not recall his having used exactly this phrase) were constant and often very telling. But his neglect of, yes, more than that, his positive antipathy for the systematic, the coordinational, the interdependent aspects of living nature are striking indeed, once one comes to study his works with the point definitely in mind. I have searched, vainly, both in his own writings and in those of several professed followers of his, for evidence that the conceptions organism and "organic" with the meaning these terms have to every genuine natural history biologist, enter in any definite and positive fashion into his

scientific men, indeed of all thoughtful persons. So far as concerns this vital matter the Nietzschean school is in strict accord with the "habits of philosophying," as Whewell calls it, now dominant in biology.

Listen to this, one of Nietzsche's "Apophthegms and Darts" occurring in the "Twilight of the Idols":

> I mistrust all systematisers and avoid them. The will to system is a lack of rectitude.

What a familiar sound this has to those who, from being at home in the discussions of recent speculative biology, have had dinned in their ears the doctrine that systematic zoology and botany are old-fashioned, childish and insignificant! Of course any one even moderately acquainted with Nietzsche's writings knows that what he was aiming at primarily in inveighing against systems was the systems of traditional philosophy. And undoubtedly, as Mügge remarks: "many have been drawn to him for this very reason." Presumably most persons, be they scientists or philosophers, or be they admirers or detestors of Nietzsche, would easily and willingly recognize that he knew little and cared less about the systems of natural history. They would go further and say that that fact had no essential relation to his antipathies against systems of philosophy. And this brings us back to the main point—the point to which, according to my view, men neither of science nor of philosophy have given sufficient attention, namely, that the system, the orderliness which every educated person now knows to be so greatly characteristic of living nature, must enter fundamentally into any philosophy of man and the animate world generally in order that that philosophy may be even approximately true and in any way adequate.

The following quotation from "Beyond Good and Evil" will open the way to a perception of the kindred between Neitzscheism and modern theoretical biology. He says:

> Let me be pardoned as an old philologist who can not desist from the mischief of putting his finger on bad modes of interpretation, but "Nature's conformity to law," of which you physicists talk so proudly as though—why it exists only owing to your interpretation and bad "philology." It is no matter of fact, no "text" but rather just a naïvely humanitarian adjustment and perversion of meaning, with which you make abundant concessions to the democratic instincts of the modern soul.

The items in this which specially concern us are the references to nature and democracy. Nietzsche appears to have felt as genuinely and deeply as any modern whatever the importance of "return to nature"—a cry which, though hackneyed, he was willing to adopt. For this feeling he is entitled, as an esthetic philosopher, to great credit. The keenness of perception and vigor of expression with which he protests against the repudiation of external nature, the vilification of the human body,

themselves in the great systems of historical philosophy from the later Greek period, on through the heyday of Christian theology, down into the modern era of German subjectivism, deserve the careful and sympathetic regard of every man of science. The best of his utterances under this head which I have found are contained in "Beyond Good and Evil," and "The Twilight of the Idols." The chapter on "Prejudices of Philosophers" in the first mentioned, and the sections, "The Problem of Socrates," "Reason in Philosophy," and "Morality as Anti-naturalness" deserve special mention.

The disastrous mistake made by Nietzsche and into which his disciples have followed him, was in believing that he *actually did* "return to nature." As a matter of fact he never came any nearer nature than did J. J. Rousseau, who raised such a hullabaloo a century and a half ago over the same subject, and for whom Nietzsche professed such an ardent hatred. It is easy for a student of real nature to understand why Nietzsche hated Rousseau more spleenishly, if such a thing were possible, then he hated people generally. Probably it was because he vaguely realized that he was doing just what Rousseau tried to do, *i. e., make* of nature what he would like to have it; and then saw that what Rousseau wanted nature to be was almost the antithesis of what he himself wanted it to be. While Rousseau wanted nature to be peaceful, gentle, benevolent and all that, and so easily found enough in it to make himself believe it to be essentially of this sort, Nietzsche as easily found enough in it to convince him that in its fundamentals nature is of the sort he liked; that is, selfish and powerful and hard and cruel.

Biologists ought to examine right carefully Nietzsche's famous doctrine of "Will to Power." His effort to make this a universal and all-sufficing principle of living nature had its strict counterpart, if not, indeed, its inspiration and model, in struggle survivalism of the Weismannian type. And the doctrine has degenerated into a sort of fiendish crotchet with many of Nietzsche's disciples, much as strugglism has with many biologists. And the reasoning, if reasoning it can justly be called, is much the same by the two sets of persons. "Wherever I found living matter," said Nietzsche, "I found will to power, and even in the servant I found the yearning to be master." (Thus spake Zarathustra.) As an illustration take an alligator, a great hunk of "living matter," sunning itself on a sand bank for hours at a time without so much as flopping its tail. What a striking case of willing to power! And what determination of a servant to be a master! Or if Nietzsche by chance ever looked through a microscope at the slow come-and-go of protoplasm confined within the cell membrane in a hair of a spider-lily, what a convincing proof of "will to power" and "desire for mastery" he had before him!

And one finds illustrations and arguments quite as convincing almost

every time he consults any orthodox Selectionist. For instance, such a biologist will watch with you a hornbill, a bird the size of a hen with a bill as large as the horn of a two-year-old bull, as the creature strives to get its bill out of its way so it can see its food, and then displays its ingenuity in getting the food far enough back in its immobile, bony mouth to enable it to swallow the morsel, and will explain to you without a smile how this bird and its ancestors have been able to survive in the struggle for existence because of the masterful bill! Or, coming down to pure and overwhelming logic, such a biologist will affirm (still without a smile) that you are bound to accept his explanation of the hornbill's bill unless you have some better explanation to offer! And he will go yet further (still in dead earnest) and tell you *he* and not you, must be the judge of which explanation is better. A very rudimentary sense of humor is another and by no means an unimportant trait-in-common between Nietzscheans and the dominant school of speculative biologists.

But that in particular which ought to make these biologists join with the disciples of Nietzsche in proclaiming their prophet the supreme philosopher of evolution is intimated in the above quotation,

> Nature's conformity to law is no matter of fact . . . but rather just a naïvely humanitarian adjustment and perversion of meaning with which you make abundant concessions to the democratic instincts of the modern soul.

The tap-root of the life philosophy of both groups is the dogma that the gross, easily seen living things about us everywhere and all the time are "mere outward expressions" of an Essence, deep, invisible, intangible, a comprehension of the working of which and the control of which is the goal of all life science.

To be sure, the fact that temperamentally Nietzsche was highly artistic and very little scientific made him interpret and evaluate human life in terms very different from those used by the biologists when they treat of man. But the close kindred between "Nietzsche's cloud-like visions of Eternal Recurrence and Superman" and the nebulous hereditary substance, germ plasm, and "The Fit" of most biological eugenists should not be overlooked by anybody interested in problems of human welfare. Nietzsche's followers have not been slow to see the meaning of the man-breeding proposals of our day. Mügge says:

> In Galton's Eugenics, founded upon the idea of evolution and the assumption that the human will is in some small measure capable of guiding the course of evolution, we see a scientific realization of Nietzsche's dreams.

And let no one, especially in this democratic country of ours, neglect to mark well the character of those dreams: Aristocracy carried through to its logical end. The best shall rule and "by means of force." The best shall be masters; the commonalty their slaves, literally and not figuratively. The only law shall be the law of the strong, the fit.

Those eugenists whose biological philosophy rests on germ-plasmic

far away—that they face toward an aristocracy most hateful to one who knows what democracy really means. Here again Nietzsche was more far-sighted than his biological counterparts, for he clearly saw and loudly proclaimed that supermen must be a very few very select masters with the great common "herd" their slaves.

And so our discussion turns back to its beginning. The laws of interdependence, of reciprocal connection and action which seem to pervade all living nature and bind it into a great, infinitely complex unity are only a seeming, only an outward manifestation of the ultimate Reality, so the dominating biologists accord with Nietzscheans in declaring. The "web of life" of which the ordinary man recognizes himself to be a part and which vulgar natural history strives to accurately describe and define and to naturally classify, is of little profit or interest because unreal or at best semi-real, say οἱ ἄριστοι the aristocracy of modern biology.

We may hope a generation of students of nature will arise after a while, a majority of whom will genuinely believe and act in accordance with their faith, that common sense has a real part in the interpretation of nature. And when such biologists come and succeed in making themselves heard and felt there may be ushered in an era of rule of the best who will be indeed best because they will rule according to the law of the whole and not by the law of some Being above or beneath or somewhere else outside of nature, whether called superman or the fit, or by some other name.

It is high time that natural history should "exert its due influence upon the current habits of philosophizing."

EUGENICS

By FRANZ BOAS

PROFESSOR OF ANTHROPOLOGY, COLUMBIA UNIVERSITY

THE possibility of raising the standards of human physique and mentality by judicious means has been preached for years by the apostles of eugenics, and has taken hold of the public mind to such an extent that eugenic measures have even found a place on the statute books of a number of states, and that the public conscience disapproves of marriages that are thought bound to produce unhealthy offspring.

The thought that it may be possible by these means to eliminate suffering and to strive for higher ideals is a beautiful one, and makes a strong appeal to those who have at heart the advance of humanity. Our experiences in stock and plant breeding have shown that it is feasible, by appropriate selection, to improve the breed in almost any direction that we may choose: in size, form, color; and even in physiological functions, as in the rapidity of development, in fertility or mentality. It is, therefore, more than probable that similar results may be obtained in man by careful mating of appropriately selected individuals—provided that man allows himself to be selected in the same manner as we select animals. We have also the right to assume that, by preventing the propagation of mentally or physically inferior strains, the gross average standing of a population may be raised.

Although these methods sound attractive, there are serious limitations to their applicability. It is obvious, from a purely biological point of view, that only those features that are hereditary can be affected by eugenic selection. If an individual possesses a desirable quality the development of which is wholly due to environmental causes, and that will not be repeated in the descendants, its selection will have no influence upon the following generations. It is, therefore, of fundamental importance to know what is hereditary and what not. We all know that features or color of hair and skin are hereditary; in other words, that in these respects children resemble organically their parents, no matter in what environment they may have been brought up. In other cases, however, the determining influence of heredity is not so clear. We know that stature depends upon hereditary causes, but that it is also greatly influenced by more or less favorable conditions during the period of growth. We know that rapidity of development is no less influenced by these two causes, and that, in general, the more subject

the less definitely can we speak of a controlling influence of heredity, and the less are we justified in claiming that nature, not nurture, is the deciding element. It would seem, therefore, that the first duty of the eugenist should be to determine empirically and without bias what features are hereditary and what not.

Unfortunately this has not been the method pursued; but the battle-cry of the eugenists, "Nature not nurture," has been raised to the rank of a dogma, and the environmental conditions that make and unmake man, physically and mentally, have been relegated to the background.

It is easy to see that in many cases environmental causes may convey the erroneous impression of hereditary phenomena. We know that poor people develop slowly and remain short of stature as compared to wealthy people. We may find, therefore, in a poor area, apparently a low hereditary stature, that, however, would change if the economic life of the people were changed. We may find proportions of the body determined by occupations, and apparently transmitted from father to son, provided both father and son follow the same occupation. It is obvious that the more far-reaching the environmental influences are that act upon successive generations, the more readily will a false impression of heredity be given.

Here we reach a parting of the ways of the biological eugenist and the student of human society. Most modern biologists are so entirely dominated by the notion that function depends upon form, that they seek for an anatomical basis for all differences of function. To give an instance: they are inclined to assume that higher civilization is due to a higher type; that better health depends upon a better hereditary stock; and so on. The anthropologist, on the other hand, is convinced that many different anatomical forms can be adapted to the same social functions; and he ascribes, therefore, greater weight to the functions, and believes that in many cases differences of form may be adaptations to different functions. He believes that different types of man may reach the same civilization, that better health may be produced by better bringing up of any of the existing types of man. The anatomical differences to which the biologist reduces social phenomena are hereditary; the environmental causes which the anthropologist sees reflected in human form are individually acquired, and not transmitted by heredity. It would lead us too far to prove the correctness of the anthropologist's view. It must suffice to point out a very few examples. Sameness of language acquired under the same linguistic environment by members of the most diverse human types, sameness of food selected from among the products of nature by people belonging to the same cultural area, similarity of movements required in industrial pursuits, the habits of sedentary or nomadic life, all of which are distributed

without any reference to physical type, will illustrate that there is ample evidence showing the lack of relation between social habits and physical type.

The serious demand must, therefore, be made that eugenists cease to look at the forms, functions, and activities of man from the dogmatic point of view according to which each feature is assumed to be hereditary, but that they begin to examine them from a more critical point of view, requiring that in each and every case the hereditary character of a trait must be established before it can be assumed to exist.

The question at issue is well illustrated by the extended statistics of cacogenics, of the histories of defective families. Setting aside for a moment cases of hereditary pathological conditions, we find that alcoholism and criminality are particularly ascribed to hereditary causes. When we study the family histories in question, we can see often, that, if the individuals had been protected by favorable home surroundings and by possession of adequate means of support against the abuse of alcohol or other drugs as well as against criminality, they would not have fallen victims to their alleged hereditary tendencies, any more than many a weakling who is brought up under favorable circumstances. Their resistance to the temptations of their environment would have entitled them to be classed as moral heroes. The scales applied to the criminal family and to the well-to-do are clearly quite distinct; and, so far as heredity is concerned, no more follows from the collected data of delinquency than would follow from the fact that in an agricultural community the occupation of farming descends from father to son.

Whether or not constitutional debility based on hereditary causes may also be proved in these cases, is a question by itself that deserves attention; but neither can it be considered as proved, nor do we grant that the selection of delinquents would eliminate all those who possess equal constitutional debility.

Basing our views on the observed fact, that the most diverse types of man may adapt themselves to the same forms of life, I claim that, unless the contrary can be proved, we must assume that all complex activities are socially determined, and not hereditary; that a change in social conditions will change the whole character of social activities without influencing in the least the hereditary characteristics of the individuals concerned. Therefore, when the attempt is made to prove that defects or points of excellence are hereditary, it is essential that all possibility of a purely environmentally or socially determined repetition of ancestral traits be excluded.

If this rigidity of proof is insisted on, it will appear that many of the data on which the theory of eugenics is based are unsatisfactory, and that much greater care must be exerted than finds favor with the enthusiastic adherents of eugenic theories.

All this does not contradict the fact that individual physical and mental characteristics are hereditary, and that, by proper selection from among the large series of varying individual forms that occur among all types of people, certain strains might be selected that have admirable qualities, while others might be suppressed that are not so favored.

It is claimed that the practical application has become a necessity because among all civilized nations there is a marked tendency to general degeneration. I do not believe that this assertion has been adequately proved. In modern society the conditions of life have become markedly varied as compared with those of former periods. While some groups live under most favorable conditions, that require active use of body and mind, others live in abject poverty, and their activities have more than ever before been degraded to those of machines. At the same time, the variety of human activities is much greater than it used to be. It is, therefore, quite intelligible that the functional activities of each nation must show an increased degree of differentiation, a higher degree of variability. Even if the general average of the mental and physical types of the people has remained the same, there must be a larger number now than formerly who fall below a certain given low standard, while there must also be more than formerly who exceed a given high standard. The number of defectives can be counted by statistics of poor relief, delinquency and insanity, but there is no way of determining the increase of those individuals who are raised above the norm of a higher standard. Therefore they escape our notice. It may, therefore, very well be that the number of defectives increases, without, however, influencing the value of a population as a whole, because it is merely an expression of an increased degree of variability.

Added to this is the fact that, arbitrarily selected, absolute standards do not retain their significance. Even if no change in the absolute standard should be made, the degree of physical and mental energy required to keep one's self under modern conditions above a certain minimum of achievement is greater than it used to be. This is due to the greater complexity of our life and to the increasing number of competing individuals. Greater capacity is required to attain a high degree of prominence than was needed in other periods of our history. The claim that we have to contend against national degeneracy must, therefore, be better substantiated than it is now.

This problem is further complicated by the advances of public hygiene, which have had the result of lowering infant mortality, and thus have brought about a change in the composition of the population, in so far as many who would have succumbed to deleterious conditions in early years enter into the adult population and must have an influence upon the general distribution of vitality.

There is still another important aspect of eugenics that should

for human ills. The radical eugenist treats the problem of procreation from a purely rationalistic point of view, and assumes that the ideal of human development lies in the complete rationalization of human life. As a matter of fact, the conclusions to be drawn from the study of the customs and habits of mankind show that such an ideal is unattainable, and more particularly that the emotions clustering about procreation belong to those that are most deeply seated in the human soul, and that are ineradicable.

Here again the anthropologist and the biologist are at odds. The natural sciences do not recognize in their scheme a valuation of the phenomena of nature, nor do they count emotions as moving forces: they endeavor to reduce all happenings to the actions of physical causes. Reason alone reigns in their domain. For this reason the scientist likes to look at mental life from the same rational standpoint, and sees as the goal of human development an era of reason, as opposed to the former periods of unhealthy fantastic emotion.

The anthropologist, on the other hand, can not acknowledge such a complete domination of emotion by reason. He rather sees the steady advance of the rational knowledge of mankind, which is a source of satisfaction to him no less than to the biologist; but he sees also that mankind does not put this knowledge to purely reasonable use, but that its actions are swayed by emotions no less now than in former times, although the increase of knowledge limits the extreme forms of unreasonable emotional activities. Religion and political life, and our everyday habits, present endless proofs of the fact that our actions are the results of emotional preferences, that conform in a general way to our rational knowledge, but which are not determined by reason; that we rather try to justify our choice of action by reason than have our actions dictated by reason.

It is, therefore, exceedingly unlikely that a rational control of one of the strongest passions of man could ever succeed. If even in matters of minor importance evasion of the law is of common occurrence, this would be infinitely more common in questions that touch our inner life so deeply. The instinctive repugnance against eugenic legislation is based on this feeling.

It can not be doubted that the enforcement of eugenic legislation would have a far-reaching effect upon social life, and that it would tend to raise the standard of certain selected hereditary strains. It is, however, an open question what would happen to the selected strains owing to the changed social ideals; and it is inexcusable to refuse to consider those fundamental changes that would certainly be connected with eugenic practice, and to confine ourselves to the biological effect that may be wrought, for we know that in the great mass of a healthy

population the social stimulus is infinitely more potent than the biological mechanism.

Although we are ignorant of the results of a rigid application of eugenics, a few of its results may be foretold with great certainty.

The eugenist who tries more than to eliminate the unfit will first of all be called upon to answer the question what strains are the best to cultivate. If it is a question of breeding Indian corn or chickens, we know what we want. We desire a large yield of good corn, or many eggs of heavy weight. But what do we want in man? Is it physical excellence, mental ability, creative power, or artistic genius? We must select certain ideals that we want to raise. Considering then the fundamental differences in ideals of distinct types of civilization, have we a right to give to our modern ideals the stamp of finality, and suppress what does not fit into our life? There is little doubt that we, at the present time, give much less weight to beauty than to logic. Shall we then try to raise a generation of logical thinkers, suppress those whose emotional life is vigorous, and try to bring it about that reason shall reign supreme, and that human activities shall be performed with clock-like precision? The precise cultural forms that would develop can, of course, not be foretold, because they are culturally, not biologically, determined; but there is little doubt that within certain limits the intensity of emotional life—regardless of its form—and the vigor of logical thought—regardless of its contents—could be increased or decreased by organic selection. Such a deliberate selection of qualities which would modify the character of nations implies an overestimation of the standards that we have reached, which to my mind appears intolerable. Personally the logical thinker may be most congenial to me, nevertheless I respect the sacred ideals of the dreamer who lives in a world of musical tones, and whose creative power is to me a marvel that surpasses understanding.

Without a selection of standards, eugenic practise is impossible; but if we read the history of mankind aright, we ought to hesitate before we try to set our standards for all time to come, for they are only one phase in the development of mankind.

This consideration applies only to our right to apply creative eugenic principles, not to the question whether practical results by eugenic selection can be attained. I have pointed out before how much in this respect is still hypothetical, or at least of doubtful value, because the social factors outweigh the biological ones.

At the present time the idea of creating the best human types by selective mating is hardly a practical one, because it dwells only as a desirable ideal in the minds of some enthusiasts.

The immediate application of eugenics is rather concerned with the elimination of strains that are a burden to the nation or to themselves,

and to raise the standard of humanity by the suppression of the progeny of the defective classes. I am doubtful whether eugenics alone will have material results in this direction, for, in view of the fundamental influence of environmental causes, that I set forth before, it is perfectly safe to say that no amount of eugenic selection will overcome those social conditions by means of which we have raised a poverty and disease-stricken proletariat, which will be reborn from even the best stock, so long as the social conditions persist that remorselessly push human beings into helpless and hopeless misery. The effect would probably be to push new groups of individuals into the deadly environment where they would take the place of the eliminated defectives. Eugenics alone can not solve the problem. It requires much more an amelioration of the social conditions of the poor which would also raise many of the apparently defective to higher levels.

Another aspect of the problem is of much more vital importance to mankind. The object of eugenics is the raising of a better race and to do away with increasing suffering by eliminating those who are by heredity destined to suffer and to cause suffering. The humanitarian idea of the conquest of suffering, and the ideal of raising human efficiency to heights never before reached, make eugenics particularly attractive.

I believe that the human mind and body are so constituted that the attainment of these ends would lead to the destruction of society. The wish for the elimination of unnecessary suffering is divided by a narrow margin from the wish for the elimination of all suffering. While, humanely speaking, this may be a beautiful ideal, it is unattainable. The performance of the labors of mankind and the conflict of duties will always be accompanied by suffering that must be borne, and that men must be willing to bear. Many of the works of sublime beauty are the precious fruit of mental agony; and we should be poor, indeed, if the willingness of man to suffer should disappear. However, if we cultivate this ideal, then that which was discomfort yesterday will be suffering to-day, and the elimination of discomforts will lead to an effeminacy that must be disastrous to the race.

This effect is further emphasized by the increasing demands for self-perfection. The more complex our civilization and the more extended our technical skill and our knowledge, the more energy is demanded for reaching the highest efficiency, and the less is it admissible that the working capacity of the individual should be diminished by suffering. We are clearly drifting towards that danger-line where the individual will no longer bear discomfort or pain for the sake of the continuance of the race, and where our emotional life is so strongly repressed by the desire for self-perfection—or by self-indulgence—that the coming generation is sacrificed to the selfishness of the living. The phenome-

found to take the place of the passing generations, is being repeated; and the more vigorously the eugenic ideals of the elimination of suffering and of self-development are held up, the sooner shall we drift towards the destruction of the race.

Eugenics should, therefore, not be allowed to deceive us into the belief that we should try to raise a race of supermen, nor that it should be our aim to eliminate all suffering and pain. The attempt to suppress those defective classes whose deficiencies can be proved by rigid methods to be due to hereditary causes, and to prevent unions that will unavoidably lead to the birth of disease-stricken progeny, is the proper field of eugenics. How much can be and should be attempted in this field depends upon the results of careful studies of the law of heredity. Eugenics is not a panacea that will cure human ills, it is rather a dangerous sword that may turn its edge against those who rely on its strength.

THE PSYCHOLOGY OF WISH FULFILMENT

By Professor JOHN B. WATSON
THE JOHNS HOPKINS UNIVERSITY

"IF wishes were horses beggars would ride" is a nursery saw which, in the light of recent developments in psychology, has come to have a much more universal application than it was formerly supposed to have. If the followers of the Freudian school of psychologists can be believed—and there are many reasons for believing them—all of us, no matter how apparently contented we are and how well we are supplied with the good things of the earth, are "beggars," because at one time or another and in one way or another we are daily betraying the presence of unfulfilled wishes. Many of these wishes are of such a character that we ourselves can not put them into words. Indeed if they were put into words for us we should straightway deny that such a wish is or was ever harbored by us in our waking moments. But the stretch of time indicated by "waking moments" is only a minor part of the twenty-four hours. Even during the time we are not asleep we are often abstracted, day-dreaming, letting moments go by in reverie. Only during a limited part of our waking moments are we keenly and alertly "all there" in the possession of our faculties. There are thus, even apart from sleep, many unguarded moments when these so-called "repressed wishes" may show themselves.

In waking moments we wish only for the conventional things which will not run counter to our social traditions or code of living. But these open and above-board wishes are not very interesting to the psychologist. Since they are harmless and call for the kinds of things that everybody in our circle wishes for, we do not mind admitting them and talking about them. Open and uncensored wishes are best seen in children (though children at an early age begin to show repressions). Only to-night I heard a little girl of nine say: "I wish I were a boy and were sixteen years old—I'd marry Ann" (her nine-year old companion). And recently I heard a boy of eight say to his father: "I wish you would go away forever; then I could marry mother." The spontaneous and uncensored wishes of children gradually disappear as the children take on the speech conventions of the adult. But even though the crassness of the form of expression of the wish disappears with age, there is no reason to suppose that the human organism ever gets to the point where wishes just as unconventional as the above do not rise to trouble it. Such wishes, though, are immediately repressed; we never harbor them nor do we express them clearly to ourselves in our waking moments.

not especially difficult to understand. When the child wants something it ought not to have, its mother hands it something else and moves the object about until the child reaches out for it. When the adult strives for something which society denies him, his environment offers him, if he is normal, something which is "almost as good," although it may not wholly take the place of the thing he originally strove for. This in general is the process of substitution or sublimation. It is never complete from the first moment of childhood. Consequently it is natural to suppose that many of the things which have been denied us should at times beckon to us. But since they are *banned* they must beckon in devious ways. These sometime grim specters both of the present and of the past can not break through the barriers of our staid and sober waking moments, so they exhibit themselves, at least to the *initiated,* in shadowy form in reverie, and in more substantial form in the slips we make in conversation and in writing, and in the things we laugh at; but clearest of all in dreams. I say the meaning is clear to the initiated because it does require special training and experience to analyze these seemingly nonsensical slips of tongue and pen, these highly elaborated and apparently meaningless dreams, into the *wishes* (instinct and habit impulses) which gave them birth. It is fortunate for us that we are protected in this way from having to face openly many of our own wishes and the wishes of our friends.

A few years ago when this doctrine was first advanced by Sigmund Freud, the noted psycho-pathologist at Vienna, it raised a storm of opposition, not only from the staid, home-loving, every-day men and women, but from scientific men as well (objection to the view seems to stand in almost direct ratio to the amount of repression the individual possesses). The truth of the matter is that Freud wrote mainly for his medical colleagues, but his words were taken up and bandied about by the press and by men who had not seriously studied them. This unjust treatment of Freud led a few physicians in this country, who had had personal contact with him, to champion his cause and to go so far as to say that they alone, with Freud, knew how to interpret dreams. Freudianism thus became a kind of cult, and the only devotees allowed openly to worship at the shrine were those who had had personal training under Freud. Fortunately science is objective, and whatever good there is in one man's work can usually be verified, although in the process of verification modifications are usually made which lead gradually to a satisfactory working basis. This belief in the objective nature of science has led many psychologists in this country who have not been fortunate enough to have personal contact with Freud to try out his methods and to attempt to verify his findings for themselves. They can do this without necessarily putting themselves on record as being

interpreters of Freud. The psychologist's interest in this movement lies in its possible usefulness in analyzing character. The analysis of personal character, like the analysis of emotions, has always resisted the efforts of the psychological laboratories. I believe all psychologists will agree with me when I say that no laboratory-developed test has ever enabled us to tell whether a man is at heart a liar, a profligate, or a coveter of his neighbor's wife.

Suppressed Wishes expressed in the Slips of Every-day Life

In social gatherings where there is some slight emotional strain and the customary control over speech is off, we find numberless examples of the expression of the suppressed wish. If we were to make a tabulation of such slips met with in a single week, the list would be long. Most of the slips reveal too much to be put down in print. But I can mention some of the types usually met with.

An elderly bachelor, the friend of the family, squires his friend's wife to a dance. He introduces her as "Mrs. S." (giving her maiden name instead of her married name, "Mrs. J."). If taxed with possessing the wish that the woman were single so that he might have another chance, he would indignantly deny that any such thought had ever crossed his mind. This is probably true in the sense that had any such wish crossed his mind in his ordinary waking moments it would have been put down immediately—repressed. It is rather interesting to note in the above case, which is an actual one, that later in the evening the "Mrs. J." referred to, after having danced with a man other than her escort, shortly afterwards introduced her partner as "Mr. J." (her husband)! It is of course unusual to find material so readily as this. I noted another and common type of slip the same day as the above. A woman of my acquaintance had to go to the New York Central Station to meet three girl friends *en route* from Boston to Washington. She decided to buy some flowers for each of them. I went to the florist shop with her and to my surprise she purchased only two bouquets, saying: "*A* likes violets, but *B* is fond of orchids." When we reached the sidewalk I asked her why she disliked "*C*" so much. "Why do you think I dislike her?" she asked. "Because," I said, "you have done all in your power to annihilate her—you have forgotten to purchase any flowers for her." She showed confusion but gracefully admitted that I had saved her from making a serious *faux pas*. To take revenge, however, she gave me my just deserts by saying: "I can't bear to be around a man who has your view of life." (She afterwards admitted, however, that "*C*" had been for many years a thorn in the flesh.)

Slips are often expressive of wishes which bear on the pleasanter side of life. I mislay my cane and umbrella, both of which I prize

had dinner and a game of bridge. The wish shortly to visit so pleasant a place again is very clearly implied. To take a single final example in this connection: Only a moment ago it was necessary for me to call a man on the telephone. I said: "This is Dr. John B. Watson, of the Johns Hopkins Hospital," instead of Johns Hopkins University. One skilled in analysis could easily read in this slight slip the wish that I had gone into medicine instead of into psychology (even this analysis, though, would be far from complete).

Slips of the pen are just as numerous and just as interesting revealers of hidden character as are slips in speech. It is in dreams, however, that we get our most interesting and valuable material for analysis.

The Dream as a Vehicle of Wish Fulfilment

According to the now generally accepted viewpoint we dream almost constantly. If we were to put the question: "Do you often dream?" to a group of men, women and children, the answers would be various. Most of the men would say: "I seldom dream, and when I do my dreams are meaningless and uninteresting." Some of the women would say that they often have wonderful and thrilling dreams while others would maintain that their dreams were few and had no interest. The children would tell us that they dreamed frequently and that their dreams were always interesting and exciting. It is difficult to convince most adults that if they do not dream constantly they do dream much more frequently than they are at present aware of. Even my own students are at first sceptical about the universality of the dream processes. I ask them to try hard to recall their dreams on waking in the morning, and if they awake in the night to jot down a sentence or two of their dreams so that they can recall the whole dream on awaking in the morning. In a short time most of them are convinced that they do dream almost constantly.

If it is difficult to convince one that he dreams constantly, it is a Herculean task to convince him of the second step in understanding dreams—to wit, that his dreams are *not* at bottom bizarre and meaningless, but, on the contrary, that they are orderly, logical, and, if we know the history of the individual, almost predictable. We must admit immediately that if we take the dream at its face value, that is, read the words that the dreamer puts down as a true report of his dream, it is a creature of fancy in the wildest sense of that word. We get the reports in bits with no apparent connecting links. Fanciful words are put in. Names are mentioned which are the names of no individuals known to the dreamer. Places are visited which have never been visited by the dreamer. (Yet in almost every dream the starting point is some

incident—situation, person, place, or thing—met with by the dreamer at some time not twenty-four hours before the dream took place.)

We get our clue to the dream as being a wish fulfilment by taking the dreams of children. Their dreams are as uncensored as is their conversation. Before Christmas my own children dreamed nightly that they had received the things they wanted for Christmas. The dreams were clear, logical and open wishes. Why should the dreams of adults be less logical and less open unless they are to act as concealers of the wish? If the dream processes in the child run in an orderly and logical way, would it indeed not be curious to find the dream processes of the adult less logical and full of meaning?

This argument gives us good *a priori* grounds for supposing that the dreams of adults too are full of meaning and are logical; that there is a wish in every dream and that the wish is fulfilled in the dream. The reason dreams appear illogical is due to the fact that if the wish were to be expressed in its logical form it would not square with our every-day habits of thought and action. We should be disinclined to admit even to ourselves that we have such dreams. Immediately upon waking only so much of the dream is remembered, that is, put into ordinary speech, as will square with our life at the time. The dream is "censored," in other words.

The question immediately arises who is the censor or what part of us does the censoring? The Freudians have made more or less of a "metaphysical entity" out of the censor. They suppose that when wishes are repressed they are repressed into the "unconscious," and that this mysterious censor stands at the trapdoor lying between the conscious and the unconscious. Many of us do not believe in a world of the unconscious (a few of us even have grave doubts about the usefulness of the term consciousness), hence we try to explain censorship along ordinary biological lines. We believe that one group of habits can "down" another group of habits—or instincts. In this case our ordinary system of habits—those which we call expressive of our "real selves"—inhibit or quench (keep inactive or partially inactive) those habits and instinctive tendencies which belong largely in the past.

This conception of the dream as having both censored and uncensored features has led us to divide the dream into its specious or manifest content (face value, which is usually nonsensical) and its latent or logical content. We should say that while the manifest content of the dream is nonsensical, its true or latent content is usually logical and expressive of some wish that has been suppressed in the waking state.

On examination the manifest content of dreams is found to be full of symbols. As long as the dream does not have to be put into customary language, it is allowed to stand as it is dreamed—the sym-

some features are uncensored. Symbolism is much more common than is ordinarily supposed. All early language was symbolic. The language of children and of savages abounds in symbolism. Symbolic modes of expression both in art and in literature are among the earliest forms of treating difficult situations in delicate and inoffensive ways. In other words, symbols in art are a necessity and serve the same purpose as does the censor in the dreams. Even those of us who have not an artistic education, however, have become familiar with the commoner forms of symbolism through our acquaintance with literature. In the dream, when the more finely controlled physiological processes are in abeyance, there is a tendency to revert to the symbolic modes of expression. This has its use, because on awaking the dream does not shock us, since we make no attempt to analyze or trace back in the dream the symbol's original meaning. Hence we find that the manifest content is often filled with symbols which occasionally give us the clue to the dream analysis.

The dream then brings surcease from our maladjustments: If we are denied power, influence, or love by society or by individuals, we can obtain these desiderata in our dreams. We can possess in dreams the things which we can not have by day. In sleep the poor man becomes a Midas, the ugly woman handsome, the childless woman surrounded by children, and those who in daily life live upon a crust, in their dreams dine like princes (after living upon canned goods for two months in the Dry Tortugas, the burden of my every dream was food). Where the wished-for things are compatible with our daily code, they are remembered on awaking as they were dreamed. Society, however, will not allow the unmarried woman to have children, however keen her desire for them. Hence her dreams in which the wish is gratified are remembered in meaningless words and symbols.

Biological Basis of the Wish

Long before the time Freud's doctrine saw the light of day, William James gave the key to what I believed to be the true explanation of the wish. Thirty years ago he wrote:

> . . . I am often confronted by the necessity of standing by one of my selves and relinquishing the rest. Not that I would not, if I could, be both handsome and fat and well dressed, and a great athlete, and make a million a year, be a wit, a *bon-vivant,* and a lady-killer, as well as a philosopher; a philanthropist, a statesman, a warrior, and African explorer, as well as a "tone-poet" and a saint. But the thing is simply impossible. The millionaire's work would run counter to the saint's; the *bon-vivant* and the philanthropist would trip each other up; the philosopher and the lady-killer could not well keep house in the same tenement of clay. Such different characters may conceivably at the outset of life be alike *possible* to a man. But to make any one of them actual, the rest must more or less be suppressed.

ganism is instinctively capable of developing along many different lines, but that due to the stress of civilization some of these instinctive capacities must be thwarted. In addition to these impulses which are instinctive, and therefore hereditary, there are many habit impulses which are equally strong and which for similar reasons must be given up. The systems of habits we form (*i. e.*, the acts we learn to perform) at four years of age will not serve us when we are twelve, and those formed at the age of twelve will not serve us when we become adults. As we pass from childhood to man's estate, we are constantly having to give up thousands of activities which our nervous and muscular systems have a tendency to perform. Some of these instinctive tendencies born with use are poor heritages; some of the habits we early develop are equally poor possessions. But, whether they are "good" or "bad," they must give way as we put on the habits required of adults. Some of them yield with difficulty and we often get badly twisted in attempting to put them away, as every psychiatric clinic can testify. It is among these frustrated impulses that I would find the biological basis of the unfulfilled wish. Such "wishes" need never have been "conscious" and *need never have been suppressed into Freud's realm of the unconscious.* It may be inferred from this that there is no particular reason for applying the term "wish" to such tendencies. What we discover then in dreams and in conversational slips and other lapses are really at heart "reaction tendencies"—tendencies which we need never have faced nor put into words at any time. On Freud's theory these "wishes" have at one time been faced and put into words by the individual, and when faced they were recognized as not squaring with his ethical code. They were then immediately "repressed into the unconscious."

A few illustrations may help in understanding how thwarted tendencies may lay the basis for the so-called unfulfilled wish which later appears in the dream. One individual becomes a psychologist in spite of his strong interest in becoming a medical man, because at the time it was easier for him to get the training along psychological lines. Another pursues a business career—when, if he had had his choice, he would have become a writer of plays. Sometimes on account of the care of a mother or of younger brothers and sisters, a young man can not marry, even though the mating instinct is normal; such a course of action necessarily leaves any unfulfilled wishes and frustrated impulses in its train. Again a young man will marry and settle down when mature consideration would show that his career would advance much more rapidly if he were not burdened with a family. Again, an individual marries, and without even admitting to himself that his marriage is a failure, he gradually shuts himself off from any emo-

tional expression—protects himself from the married state by sublimating his natural domestic ties; usually in some kind of engrossing work, but often in questionable ways—by hobbies, speed manias and excesses of various kinds. In connection with this it is interesting to note that the automobile, quite apart from its utilitarian value, is coming to be a widely used means of repression or wish sublimation. I have been struck by the enormously increasing number of women drivers. Women in the present state of society have not the same access to absorbing kinds of work that men have (which will shortly come to be realized as a crime far worse than that of the Inquisition). Hence their chances of normal sublimation are limited. For this reason women seek an outlet by rushing to the war as nurses, in becoming social workers, pursuing aviation, etc. Now if I am right in this analysis these unexercised tendencies to do things other than we are doing are never quite got rid of. We can not get rid of them unless we could build ourselves over again so that our organic machinery would work only along certain lines and only for certain occupations. Since we can not completely live these tendencies down we are all more or less "unadjusted" and ill adapted. These maladjustments are exhibited whenever the brakes are off, that is, whenever our higher and well-developed habits of speech and action are dormant, as in sleep, in emotional disturbances, etc.

Many but not all of these "wishes" can be traced to early childhood or to adolescence, which is a time of stress and strain and a period of great excitement. In childhood the boy often puts himself in his father's place; he wishes that he were grown like his father and could take his father's place, for then his mother would notice him more and he would not have to feel the weight of authority. The girl likewise often becomes closely attached to her father and wishes her mother would die (which in childhood means to disappear or go away) so that she could be all in all to her father. These wishes, from the standpoint of popular morality, are perfectly innocent; but as the children grow older they are told that such wishes are wrong and that they should not speak in such a "dreadful" way. Such wishes are, then, gradually suppressed, replaced by some other mode of expression. But the replacement is often imperfect. The apostle's saying "When we become men we put away childish things" was written before the days of psycho-analysis. We do not put them away—we replace them, but they never for us completely lose their impulsive power. Parents who show excessive emotional reactions towards their children—overmuch fondling of them—often encourage these wishes. The children take on more and more the wished-for forms of attachment. Later on in life such wishes may show themselves in dreams and occasionally in more objective ways. Now and then we find a young man whose mother has long since

probably be the first one to scoff at the true explanation. In a similar way adults may become too much attached to children. This is often seen in the case of a woman whose husband has died leaving her with an only son. The son becomes substituted for the father, and her reactions which she looks upon as those belonging merely to a devoted mother, soon take on certain characteristics of those she would show to her husband. (The mother usually objects to the marriage of the son—on the grounds usually that the girl is not "suited to him.") Again from a moral point of view, as we ordinarily understand the term, her actions are exemplary. When I have expressed these views I have been often indignantly asked if parents should not caress their children. Of course I answer "yes"; but certainly if Freud has taught us anything, it is to give heed to our relations with our children. Overindulgence in caresses is far worse for their future happiness and poise than is overindulgence in material things.

The analysis of dreams is a field which belongs to the specially qualified physician—the psycho-analyst. It sometimes takes weeks, months and even years, to give genuine analysis of a dream. Special psycho-analytic methods are necessary to the unraveling of dreams, as well as special skill in handling the subject. Hence the dream will probably never mean any more to the ordinary individual than it does to-day. The crass analyses of friends and neighbors are worthless, nor should one be disturbed over a dream because someone has told him that Freud would say such and such things about it.

Dream analysis when made by experts has been of almost unbelievable service in treating the functional nervous diseases (neurasthenia, psychasthenia, hysteria, etc.). The dreams of such patients reveal their past in sections: the physician gradually joins these sections and can tell the patient where the trouble lies (that is, tell him the wishes around which all his dreams revolve). Knowing the cause of his distress, the patient, assisted by the physician, can form *new sets of habits which do not conflict*. Cures are thus effected without the use of drugs. The cures, however, smack not at all of the mysterious.

I have already expressed the wish that technical psycho-analysis may lead finally over into genuine character analysis. Many men high up in the business world, the diplomatic service, and in government positions generally, often have enormous responsibilities put upon them—there are times in the lives of such men when they are put under terrific strain from the outside: such men should be relatively free from strong inward conflicts and repressions. It seems fantastic to say that such persons ought to be selected only after careful psycho-analysis, but the whole essence of the psycho-analytic movement strongly suggests such a procedure.

WAR AND THE SURVIVAL OF THE FITTEST

BY PROFESSOR I. W. HOWERTH

UNIVERSITY OF CALIFORNIA

"THE survival of the fittest" is a phrase coined by Herbert Spencer and first used by him in his "Principles of Biology,"[1] published in 1864. By this phrase he sought to express in purely mechanical terms the operation of nature in the evolution of organisms, a process which Darwin had called "natural selection or the preservation of favored races in the struggle for life." Alfred Russel Wallace, who shares with Darwin the honor of discovering the principle of natural selection, recognized at once the advantages of Spencer's phrase and wrote to Darwin urging its acceptance as a substitute for "natural selection." He said:

> It is a plain expression of the fact, while natural selection is a metaphorical expression of it and to a certain degree incorrect, since . . . nature does not so much select special varieties as exterminate the most unfavorable ones.

But Darwin, while perceiving the advantages of the phrase and admitting its greater accuracy, pointed out the objection that it can not be used as a substantive governing a verb. He also regards the bringing into connection of natural and artificial selection by the term "natural selection" as an advantage not to be overlooked, and the wide use of the term both at home and abroad made him doubtful whether it could be given up. "With all its faults," he said, "I should be sorry to see the attempt made." In the later editions of the "Origin of Species," Darwin used "survival of the fittest" as an alternative of "natural selection"; and Spencer in his subsequent writings used both phrases with something like equal frequency.[2]

"The survival of the fittest," then, and "natural selection" are two expressions for practically the same thing, namely, the mode of descent of organisms and groups of organisms from earlier and simpler forms. This mode briefly stated is as follows: The conditions of life necessitate on the part of all living things a struggle for existence, and this struggle is intensified by the procreative powers of animals and plants, more being brought into existence than can possibly survive; in all organisms there is a tendency to vary and in the struggle the organisms which

[1] Spencer, Herbert, "Principles of Biology," Vol. I., p. 530. Revised and enlarged edition, New York, 1898.

[2] See "Life and Letters of Charles Darwin," II., pp. 229–30, N. Y., 1901.

enables them to live and reproduce their kind while those not so favored are eliminated; this favorable variation reappears in the progeny of those that survive, by virtue of the tendency of like to produce like, and thus each succeeding generation becomes more closely adapted to the special circumstances of its life, and there is a gradual change of the species in the direction of better and better adaptation to these circumstances.

Assuming, then, the primordial existence of organisms with a tendency to vary, we have in "natural selection" or "the survival of the fittest" an explanation of how all living creatures (and the explanation holds for societies as well) have come to be what they are, in so far, at least, as their development has not been directly and consciously affected by human effort. It is not the entire explanation, to be sure. Darwin himself did not regard it as such. "I am convinced," he said, "that natural selection has been the most important, but not the exclusive, means of modification."[3] But, so far as it goes, it may be accepted as a true account of how evolution has taken place. "Natural selection" or "the survival of the fittest" is a law of nature.

Now what is the significance of this law of nature with respect to the possibility and desirability of eliminating the curse of war? Some declare that such elimination is undesirable because, as they believe, it is by war that social progress has been achieved; and impossible, also, because war, they assert, is a manifestation of a fixed and unchanging biological and social law. And so we find in current discussions of war frequent reference to "the inviolable laws of nature," and this particular biological and social law of the survival of the fittest is adduced ofttimes as a bar to the promotion of peace. It is brought forward with the idea, apparently, that it gives a peculiarly scientific and conclusive aspect to all arguments against the efforts and hopes of the advocates of peace. To expect or desire the cessation of war, we are told, is to disregard the law of the survival of the fittest, and the natural means of social advancement; it is Utopian, and Utopian is, with many, merely a polite substitute for chimerical, vagarious or nonsensical. Let us see whether this law has really anything to do with the possibility of eliminating war.

Since the promulgation of the evolutionary philosophy the doctrine of the survival of the fittest has been most frequently proclaimed in justification of the present competitive system of industry. Competition, it is said, is a law of nature, and the sole motive to human effort, though how a law may become a motive is never clearly explained.

[3] "Origin of Species," sixth London edition, p. 5.

from an editorial in the Saturday *Evening Post:*

Competition—the struggle to the death for life and hope—is not, in most of its outer manifestations, a pretty thing. If any man had invented it he would have got hard words from the Utopian, but it happens to have been invented by the Creator of All Things and to be the motive power in evolutionary advancement from the first Protozoan to Shakespeare.

It would be hard to find in equal space a more fallacious collocation of ideas. Competition is not necessarily "a struggle to the death"; hope is not its object; to proclaim it as an invention of the Creator is merely an appeal to religious prejudice, and it has not been the motive power in evolutionary advancement "from the first Protozoan to Shakespeare." It would be easy to show directly the fallacies of such reasoning. They will appear, however, in the course of this discussion if it be kept in mind that war is itself a form of competition. Anything applicable to the one subject is therefore applicable to the other.[4] We shall confine our attention here to the law of the survival of the fittest as it relates to the subject of war.

For an illustration of the current teachings concerning the necessity of war as evidenced by the biological law of evolution, we turn to Bernhardi's book on "Germany and the Next War." It offers by no means the only example of such teachings; current articles in English and American periodicals on the nature of war and the necessity of preparedness would serve our purpose quite as well; but it happens to be at hand and all we need is a definite and formal statement of the doctrines to be discussed. Says Bernhardi:

War is a biological necessity of the first importance, a regulative element in the life of mankind which can not be dispensed with since without it an unhealthy development will follow, which excludes every advancement of the race, and therefore all real civilization. "War is the father of all things." The sages of antiquity long before Darwin recognized this.

He quotes with approval the following from Claus Wagner's "Der Krieg als schaffendes Weltprinzip":

The natural law, to which all laws of Nature can be reduced, is the law of struggle. All intrasocial property, all thoughts, inventions, and institutions, as indeed, the social system itself, are a result of the intrasocial struggle, in which one survives and another is cast out. The extrasocial, the supersocial, struggle which guides the external development of societies, nations and races, is war. The internal development, the intrasocial struggle, is man's daily work—the struggle of thoughts, feelings, wishes, sciences, activities. The outward development, the supersocial struggle, is the sanguinary struggle of nations—war.

[4] See Howerth, I. W., "Work and Life," Chap. V., New York, 1912, for an extended discussion of competition, natural and industrial.

> Struggle is, therefore, a universal law of nature, and the instinct of self-preservation which leads to struggle is acknowledged to be a natural condition of existence.

He concludes that war is an unqualified necessity, justifiable from every point of view, and that

> the efforts directed towards the abolition of war must not only be termed foolish, but absolutely immoral, and must be stigmatized as unworthy of the human race. . . . The whole idea represents a presumptuous encroachment on the natural laws of development which can only lead to the most disastrous consequences for humanity generally.

We purpose to show that these arguments, if arguments they may be called, betray a gross misconception of "nature," "biological necessity" and "the law of struggle." If sufficiently clear, and if attended to, the demonstration should carry the conviction that the shallowness and ignorance implied by such teachings are equaled only by their obvious viciousness. Let us begin by analyzing the struggle for existence in order to see whether the universality of this struggle is proof of the impossibility of abolishing war.

When we analyze the struggle for existence, as carried on either by biological organisms or by nations, we find that it involves not only a competitive struggle of organism against organism or nation against nation, but also a struggle against natural conditions. In so far as it is a struggle against nature, it has nothing to do with war; it would remain if war were eliminated. Moreover international competition manifests itself not only in war, but also in commerce, art, science, etc. Only rarely does it degenerate into war. War, then, is only a part of the struggle for existence. It is merely a phase of this struggle. Its elimination would not in the least interfere with the great law of struggle. If the nations of the world should become Christian, in fact as well as in name, and the principles of love and brotherhood should prevail throughout the world, there would still be plenty of opportunity for struggle afforded by nature, and by human nature, and progress need not be delayed. The law of progress is action, and action need not be of the destructive nature of war.

What are we to say, then, of this doctrine that the supersocial struggle for existence is the sanguinary struggle of nations—of the doctrine "that war is as necessary as the struggle of the elements in nature"?[5] What reply are we to make to the contention that blood-letting is necessary to the virility of nations; that international conflict is to be looked upon as a means of salvation from the degenerating in-

[5] Quoted by Bernhardi, from A. W. von Schelegel.

often implied if not expressed by that phrase, is the highest manifestation of the true grandeur of man and of nations? Merely this, that it mistakes the necessity of social action for the necessity of a particular kind of action, that is, war, and betrays a misconception of the laws of evolution or a painful indifference to the social consequences of the epigrammatical expression of half-truths. Action is a necessity both of individual and of social life. We must act if we would live, and it is commendable to rouse nations to intelligent action, but it does not follow from this that nations are under the inevitable necessity of making war upon one another. We Americans, for instance, must manifest activity or we shall stagnate, but we need not on that account intervene in Mexico or provoke war with the Japanese. We have enough to do at home to evoke all the activity and all the intelligence of which we are capable. There are, and will always be, problems of production, distribution, education, sanitation. Concerted action in swatting the fly or killing mosquitoes, to say nothing of organized action to redeem our arid lands, to reforest our devastated hills, and to harvest the riches of mountains and plains, affords ample opportunity for the exercise of all our energies, are in reality far more dignified occupations than the destruction of property and life in war, and the glory to be won therefrom will eclipse the showy nonsense of war if society ever awakens from its present illusion. The struggle for existence, we repeat, does not necessarily involve war. Man can be strenuous without being destructive.

But, while war is only an incident in the struggle for existence and might therefore be eliminated without serious interference with that struggle, yet, on the whole and in general, it results in the survival of the fittest. Is this not a sufficient reason why it should not be abolished, even if it were possible for society to do so? Would not continuous peace among nations necessitate the abrogation of the law of the survival of the fittest and defeat the progress which is achieved by such survival? Let us consider this question squarely on its merits. We shall see that the fact that war does admittedly result in the survival of the fittest is no reason whatever why war should be condoned or encouraged.

First, let us observe that evolution is not necessarily progressive, that it may lead to degradation, as in the case of the parasite, as well as to the development of a paragon of strength and beauty. The downfall of the Roman Empire was as much a phenomenon of social evolution as the rise of the Dutch republic. In the evolutionary process the survivors are indeed the fittest, but the fittest are not necessarily the best; they are not always better from an ethical standpoint than those whom they supplant; they are merely those who are best adapted to the prevailing conditions. Of course no one who really understands the doctrine of evolution needs instruction on this point. Spencer long ago

pointed out "that the fittest throughout a wide range of cases—perhaps the widest range—are not "the best."[6] Professor Huxley is quite as explicit on this point. In a well-known passage he says:

> There is another fallacy which appears to me to pervade the so-called "ethics of evolution." It is the notion that because, on the whole, animals and plants have advanced in perfection of organization by means of the struggle for existence and the consequent "survival of the fittest"; therefore men in society, men as ethical beings, must look to the same process to help them towards perfection. I suspect that this fallacy has arisen out of the unfortunate ambiguity of the phrase "survival of the fittest," "Fittest" has a connotation of "best"; and about "best" there hangs a moral flavor. In cosmic nature, however, what is "fittest" depends upon the conditions. Long since, I ventured to point out that if our hemisphere were to cool again, the survival of the fittest might bring about, in the vegetable kingdom, a population of more and more stunted and humbler and humbler organisms, until the "fittest" that survived might be nothing but lichens, diatoms, and such microscopic organisms as those which give red snow its color; while, if it became hotter the pleasant valleys of the Thames and the Isis might be uninhabitable by any animated beings save those that flourish in a tropical jungle. They, as the fittest, the best adapted to the changed conditions, would survive.[7]

Since the survival of the fittest does not necessarily result in progress, what becomes of the argument that war is essential to progress because it results in the survival of the fittest? Plainly it is unfounded. As a matter of fact this "law of nature" has no more bearing upon the wisdom or expediency of striving to abolish war than the law of gravitation has upon the possibility of success in aviation.

The idea then that war is "a moral obligation" because it results in the survival of the fittest is as unwarranted as the inference from the law of the struggle for existence that it is a "biological necessity." Hence the related idea that it is impossible and undesirable to abolish war betrays a very imperfect conception of the laws of biology and of social advancement.

The prevalent notion with regard to the survival of the fittest is belied by the commonest experiences of life. In wild life, among animals, for instance, the fittest are determined usually though not always by battle, but under domestication the fittest are determined by the application of intelligent tests. No precedent stockman would encourage battle among his flocks and herds in order to determine the fittest. He would not even look with indifference upon such a battle, or with the optimistic hope that "somehow good will be the final goal of ill." He would see at once not only its waste, but also, the improbability of his deriving anything but accidental good from

[6] See Spencer, H., "Mr. Martineau on Evolution," Essays, Vol. I., p. 379, N. Y., 1910.

[7] Huxley, "Evolution and Ethics and other Essays," pp. 80–1.

such a battle. No man really believes in reliance upon the nat-ural law of the survival of the fittest to bring about, without direction, results in which he is immediately and personally interested. Certainly those who talk about the necessity of war and assert their belief in the natural law of the survival of the fittest do not act upon this belief in matters of personal concern. Would such persons, if a child of theirs were in battle with a ferocious animal, stand quietly by and console themselves with the reflection that the fittest will survive? Would they, if engaged in agriculture, carefully prepare the ground, sow the seed, and after the germination of the crop leave the plants to struggle with the weeds in order that the fittest might survive? Certainly not! No more should the world expect continuous progress as a result of war.

We have now seen that war is not an essential part of the struggle for existence, and that, while it results in the survival of the fittest, it does not necessarily result in progress, the reason being that the fittest are not necessarily the best. It remains to show that the whole case for war rests upon a profound misconception of the nature and significance of natural law. It will appear that the law of the survival of the fittest, instead of being an obstacle in the way of the achievement of continuous peace, is the condition that makes such achievement a possibility. First, let us consider the question: What is a law of nature?

If we think of the world in terms of the philosophy of idealism, it is a world consisting wholly in sense-impressions. Says Pearson:

> These sense-impressions appear to follow an unchanging routine capable of expression in the brief formulæ of science because the perceptive and reflective faculties are machines of practically the same type in all normal human beings.[8]

From this view a natural law is merely a brief description of the recognized sequence of sense-impressions. If, on the other hand, we regard the world as what it seems to be, namely, a collection or aggregation of material phenomena, then a natural law is merely a statement of the coexistence and sequence of such phenomena. In neither case is a law of nature what many appear to suppose it to be, that is, an expression of the will of a superior authority commanding obedience. It is a wholly mistaken idea that the laws of nature are commands, and that they are to be discovered in order to be obeyed. I suspect this idea lies at the bottom of the consciousness of those who claim that the survival of the fittest is an effective bar to the promotion of peace. They think of a natural law as in the nature of a command, and not, as it really is, a mere formula for expressing uniformity in the action of some natural force or forces so long as the conditions are the same. A natural law is not a prescription, but a description; we owe it no allegiance; the

[8] Pearson, K., "Grammar of Science," London, 1895, p. 132.

object of discovery is not obedience, but control. Every natural law that is ascertained gives us additional power over nature, inasmuch as it reveals the conditions necessary to the intelligent control of the forces of nature and to the progressive achievement of its conquest. This point is well illustrated by the progress and practical value of natural science. Why does science endeavor to achieve the discovery of natural laws in the physical world? Is it that we may regard ourselves as impotent in the presence of such laws? or that we may yield obedience to them to avoid punishment? or that we may stand aloof and allow the free and unrestricted operation of the physical forces of nature? or that we may talk learnedly of these laws as insuperable obstacles to improvement upon nature by the practical application of our intelligence? Certainly not! It is for the practical purpose of enabling man to direct the forces of nature, and for that alone. Knowledge is power. Newton's discovery of the law of gravitation has not discouraged the construction of sky-scrapers. It has merely shown the necessity of care that in such construction the center of gravity fall within the base. Instead of an obstacle to architectural achievement, the law of gravity, representing as it does the unfailing operation of a natural force, indicates the very condition of success.

The case is not different when we pass from the physical to the biological or social world. Those who think that a biological or social law of nature presents opposition to intelligent efforts to bring about biological or social progress have only to consider the daily action of man for a conclusive confutation of their view. We may take an example from the field of agriculture.

It is a well-known fact that Indian corn (*Zea Mays*) is descended from a grass not now found in a wild state, but undoubtedly very unlike the corn of to-day. Now the discoverer of this grass, if he had entertained the idea of natural law that seems to be prevalent to-day, would have said:

> This grass has attained its present development through the operation of natural forces, and in accordance with the law of the survival of the fittest. If I should attempt to further its development by any sort of effort, I should be acting contrary to a law of nature and must therefore inevitably fail.

But he did no such thing. He simply provided conditions under which, through the very operation of this law of the survival of the fittest, a better and better type of corn was produced. Why should we not do the same thing to insure the progress of nations in the direction of peace? The conditions of peace will assure a peaceful type of nation, just as the appropriate environment will produce a better type of corn. What essential difference is there between the mode of producing a "culti-

vation? Clearly there is none at all.

It is surprising, then, that the survival of the fittest, merely because it is a law of nature, should for that reason be supposed to militate against the efforts of man in behalf of peace—national, industrial and social. For if it were not a law of nature that the fittest survive, how could we expect to affect the development of an individual or of a nation by the improvement of circumstances? It would be hopeless to expect any progressive results from our efforts directed to the improvement of conditions if these conditions bore no relation to the type of individual, institution or society that develops within them? It is just because we know that nature acts in accordance with this unfailing law that we may be confident of our ability to determine the fitness either of individual or nation by intelligently controlling the conditions of life. Instead of precluding our efforts at reform or peace the laws of nature, I repeat, reveal the conditions that make possible successful efforts in this direction. If this is true of natural laws in general it is of course true of the law of the survival of the fittest. Everything that nature has developed, everything that survives, proves by its survival that it is among the fittest. In early paleozoic times certain crustacea and mollusks were the highest forms of life; in the mesozoic period huge lizards held sway, and in the miocene age the mastodon was lord of the earth. Why do not all these animals flourish now? It is merely because the "times have changed"; they are no longer the fittest. Have we not here the very secret of achieving progress? Change in conditions produces evolution. If we only change the conditions, then, so that the peaceful type of nation will be the fittest, the warring type will become as extinct as the megatherium or the dodo, and, for exactly the same reason, that is, it will no longer be fit to survive. May we not hope, then, that through the changes that must result from increased social intelligence the peaceful nations by becoming the fittest will take the place of the militant types just as the present flora and fauna of the earth have supplanted the forms of life that immediately preceded them.

In conclusion we may say that the prevalent doctrines that, since the survival of the fittest is a natural law under the operation of which the lower organisms and society have advanced to their present stage of development, we must therefore be careful not to hinder its operation, or seek to abrogate it, is false. Of course, as a matter of fact, nobody should try to "hinder" the operation of a natural law, or "encroach" upon it, and nobody with any knowledge of nature, and solicitous about the realization of ethical ends, would undertake to "abrogate" a natural law except in the sense of counteracting one natural force by another. All that we can do, all that anybody should try to do, is to take advantage of the existence of a natural law so to arrange cir-

cumstances that the result of the operation of that law will be to human advantage, that is to say, that "the fittest" may be "the best." The construction of the pyramids or the Washington Monument did not affect in the least the law of gravitation. The improvement of our grain and our live stock has not in the least affected the law of the survival of the fittest. No more would the development of a society in accordance with the highest qualities of man's nature affect that law. Natural law does not stand in the way of the one achievement any more than the other. The fittest nations will survive; it is for us to make fit the conditions. To assist us in this task is the supreme function and opportunity of science.

> *Science, d'où prévoyance; prévoyance, d'où action:* telle est la formule très-simple qui exprime, d'une manière exacte, la relation générale de la *science* et de l'*art*, en prenant ces deux expressions dans leur acceptation totale.[a]

[a] Comte, Auguste, "Philosophie Positive," Vol. I., p. 51.

A NEGLECTED FACTOR IN THE QUESTION OF NATIONAL SECURITY

BY PROFESSOR GEORGE F. ARPS

OHIO STATE UNIVERSITY

THE question of national preparation in anticipation of future international strife can not fail to consider man as he natively is, divested of the mantle of acquired behavior; he must be viewed from the standpoint of his naked natural birthright, however much it may be desirable to consider him as we wish him to be, if the question is to be answered on practical rather than idealistic grounds.

By birthright we mean that complex of inherited tendencies as we find it unencumbered, unmodified or redirected by environmental influences. This complex constitutes "original man"; it is man's inborn organization with which he begins his life-long struggle with unescapable environment. Innumerable catalogues have been made of man's native equipment (instincts, reflexes, tendencies) with which he starts the conquest of the external world. It suffices for our purpose to know that man's original complex exceeds in variety of tendencies that of any other animal, and that the virility and dominance of certain tendencies may vary endlessly with the individual.

What a man is, what he will do, is a result of the play of environmental stimuli upon the leanings, bents, tendencies, lodged in his constitution. Native endowment and environment fit each other as lock and key. The limit, character and direction of man's behavior can not transcend his original nature—a "soft pine" germ-plasm spells a soft pine character and this remains true no matter how favorably the environmental forces may be applied. By no pedagogical device has it been, or ever will be, possible to transform a weak inherited complex into an oak character.

The future security of the state or the home must not fail to regard man biologically, as possessed of powerful destructive tendencies as well as powerful tendencies of love, sympathy and kindness. "Two souls," as Faust says, "dwell within his breast," the one of sociability and helpfulness, the other of jealousy and antagonism to his mates. Wanton blindness to this poetic expression of man's dual nature wobbles the security of any nation unwilling to turn the unsmitten cheek. In this matter the evil component of man must be reckoned with the good. To cherish the latter is noble; to blink the former is not only perilous, but beggars courage.

These two apparently contradictory souls lie deeply rooted in the subsoil of man's original constitution. The sense organs like waiting funnels form gateways for environmental stimuli which, seeping through the interstices of acquired behavior, nourish the roots below.

All roots of human action, whether that of parental love or pugnacity, grow according to the degree and mode of exercise until the entire human organism is completely moulded. A nation under the drill of incessant discipline becomes a completely fashioned fighting machine.

Which of these souls, these inborn propensities, have civilized nations through all forms of educational agencies elected to nourish and preserve? Consider the space given to man's brutal activities in the histories of all nations, the melodramatic movies, the devotion of the daily press to executions, thuggery, thievery (all modifications of the Jesse James stimuli); consider, too, the content of pictorial weeklies and certain other periodicals and fictional publications dealing with deep-laid plots of "Man's inhumanity to man." These forces constitute a fair sample of environmental stimuli which arouse, keep alive and feed fat man's original glut to rapine and to plunder, to hate and fear. These are among the forces which determine the self which dominates human behavior. The wave of fear sweeping over the states to-day like a prairie fire is the expected expression of a native protective response to a very real situation. Report from the blood-stained fields of Europe, of the new and dreadful devices for the annihilation of time and space, flashes through the thin veneer of idealism and conventionalities, lays hold on the original springs of human action, brushes aside acquired behavior and strikes quick to the Faustion Self of pugnacity, fear, hatred and antagonism. Like a slow-consuming fire, civilized nations have nursed the demon of destruction which, loosened, rocks the temple of international justice, outrages the peaceful in utter disregard of solemn obligations. And this because fine words and unsupported threats are powerless in the face of deadly impulses armed with refined tools and directed with terrible sincerity to crush and kill. The rôle of these original impulsive forces of man has been recognized by the laymen. In a remarkable address recently delivered in Carnegie Hall, Elihu Root portrays man and civilization in these significant words:

> We have learned that civilization is but a veneer thinly covering the savage nature of man; that conventions, courtesies, respect for law, regard for justice and humanity, are acquired habits, feebly constraining the elemental forces man's nature developed through countless centuries of struggle against wild beasts and savage foes.

The Teutonic war machine is a product of careful nurture from

toys are given to children during the most plastic and favorably formative period of life. Inflammable youth is fed upon an inflammable diet morning, noon and night; at no time can his ears, eyes or touch escape those environmental stimuli which fall upon and make permanent his native tendency to combat, to resent, to hate. Out of this stuff European nations wove and are continuing to weave the ideational web of war. The gory field of Europe is the inevitable consequence. So sure as martial ideas are fabricated, so sure as these ideas are persistently entertained, so sure will war result, for it is the very essence of ideas to issue into action.

If it is true that environmental stimuli quicken and actualize latent tendencies and if it is equally true that failure to feed such tendencies during the ripening period tends to weaken, if not eradicate, them, then, the good John Galsworthy's statement that "this war is an operation to excise the trampling instinct" is surely open to serious question. According to the laws of instinctive development, fixation of the trampling instinct rather than excision is the inevitable consequence of the war. The iron heel of the treading, trampling instinct thrives least through inaction and is quickened, sharpened and enthroned by action in a favorable environment. War is such an environment; it unlocks the trampling heel of the dominating, professional Junker as a key loosens the lock. Junkerism resides within the breast of every man in every land and differs from mortal to mortal only in the degree of its original vigor. Excision through opportunity is a myth born of flimsier stuff than paper dreams.

Again let it be said that the question of national security can not fail to consider man's dual and original endowments. Peel off the thin veneer of conventionality, and tap him at his foundation, and one side of him stands revealed as a fighter, full of original pugnacity, anger, resentment and, under provocation, may become the most ruthlessly ferocious of beasts. These "Original Movers" fitted man to survive and are operative to-day under one guise or another. As Rochefoucauld says,

> There is something in the misfortunes of our very friends that does not altogether displease us; and an apostle of peace will feel a certain vicious thrill run through him, and enjoy a vicarious brutality, as he turns to the column in his newspaper at the top of which "Shocking Atrocity" stands printed in large letters. See how the crowds flock round a street brawl! Consider the enormous annual sale of revolvers to persons, not one in a thousand of whom has any serious intention of using them, but of whom each one has his carnivorous self-consciousness agreeably tickled by the notion, as he clutches the handle of his weapon, that he will be rather a dangerous customer to meet![1]

[1] James: "Principles of Psychology."

That man is essentially of pacific virtues rests on an assumption not sustained by his evolutionary or political history.

If it is true that powerful nations systematically nurture the demon of antagonism through all forms of educational agencies, if we rightly interpret the genesis and dynamics of ideas, and if, lastly, the human race is still in the condition of *bellum omnium contra omnes,* then, national preparedness, it seems, becomes a plain matter of duty. There is no alternative, regrettable as it is, so long as nations insist on so organizing from earliest infancy to maturity the brains of their citizens in such a way that any wholly irrelevant stimulus may pull the trigger and let loose the engines of war. Pacific nations, unprepared, but potentially powerful, must submit, under certain circumstances, to indignities which may often amount to nothing short of complete abnegation of self-respect. Who is there who does not *wish* it might be otherwise? But wishes and sentimental longings go down like chaff before the wintery blasts of energetic action. The present world disturbance demands intelligence, cold calculation, action; this is no time for any nation to swim about in a weltering sea of sensibility and emotion, no time for spineless fulminations and dreams. Nor will it be maintained that similar situations will not recur. In view of recent events, in view of what man is and what he has shown himself to be on every page of his bloody history, it would be folly, and in the long run suicidal, for any vigorous people to close deliberately their eyes to the simplest laws of human behavior.

Imperative as preparation now appears, it will be even more so after the war by reason of untold increment of economic stresses which strain immeasurably man's native good will. Future economic struggles and practises may inaugurate a low grade of trade ethics far removed from the altruistic soothing-syrup variety. The blamelessly enriched onlooker, with almost fatal surety, acts as a salve which heals the wounds, buries the differences of fierce antagonists and, under economic stresses, this onlooker incurs the unrighteous, united envy and secret, if not open, hatred of the combatants. The best is not even to be hoped for; the worst may be expected.

THE ORIGIN AND EVOLUTION OF LIFE ON THE EARTH*

By HENRY FAIRFIELD OSBORN

COLUMBIA UNIVERSITY, AMERICAN MUSEUM OF NATURAL HISTORY

LECTURE II, PART I

The Evolution of the Vertebrata

Chromatin evolution. Errors and truths in the Lamarckian and Darwinian explanations. Individuality in character origin, velocity and cooperation. Origin of the vertebrate type. The laws of convergence, divergence and of adaptive radiation in fishes and amphibians.

SIMON NEWCOMB[1] considered the concept of the rapid movement of the solar system toward Lyra as the greatest which has ever entered the human mind. The history of the vertebrates as the visible expression of the evolution of the microscopic chromatin presents a contrasting concept of the potentialities of matter in the infinitely minute state.

The peculiar significance of vertebrate chromatin is its stability in combination with incessant plasticity and adaptability to varying environmental conditions and new forms of bodily action; throughout constant changes of proportion, gain and loss of characters, genesis of new characters, there is always preserved a large part of the history of antecedent form and function, for chromatin is far more stable than the surface of the earth. In the vertebrates chromatin evolution is mirrored in the many continuous series of forms which have been discovered, also in the perfection of mechanical detail in organisms of titanic size and inconceivable complexity, like the dinosaurs among reptiles and the whales among mammals which rank with the *Sequoia* among plants.

There are two historic explanations of the causes of this wonderful process of chromatin evolution, each adumbrated in the Greek period of inquiry. The older, known as the Lamarckian, expressed in modern terms is that *the beginning of new form and new function is to be sought in the body cells* (*soma*), on the supposition that cellular actions,

* Fourth course of lectures on the William Ellery Hale Foundation, National Academy of Sciences, delivered at the meeting of the Academy at Washington, on April 17 and 19, 1916.

The author desires to express his special acknowledgments to Professor William K. Gregory of Columbia University and the American Museum of Natural History for notes and suggestions in the preparation of this section.

[1] Newcomb, Simon, "Astronomy for Everybody," Doubleday, Page & Co. November, 1902, 12mo, pp. 333.

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The Lamarckian view that adaptation in the body cells *invariably* precedes similar adaptive reaction in the chromatin is supported neither by experiment nor by observation; such precedence while occasional and even frequent is by no means invariable. The Darwinian view, namely, that chromatin evolution is a matter of fortuity and displays itself in a variety of directions, is contradicted by paleontological evidence both in the Invertebrata and Vertebrata, among which we observe that continuity in chromatin evolution prevails over the evidence either of fortuity or of sudden leaps or mutations, that *in many characters there is a prolonged rectigradation or direct evolution of the chromatin toward adaptive ends.* This is what we mean in saying that in evolution law prevails over chance.

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FIG. 3. FIRST UPPER MOLAR OF *Meniscotherium terrærubræ*.
FIG. 4. FIRST UPPER MOLAR OF *Euprotogonia puercensis*.

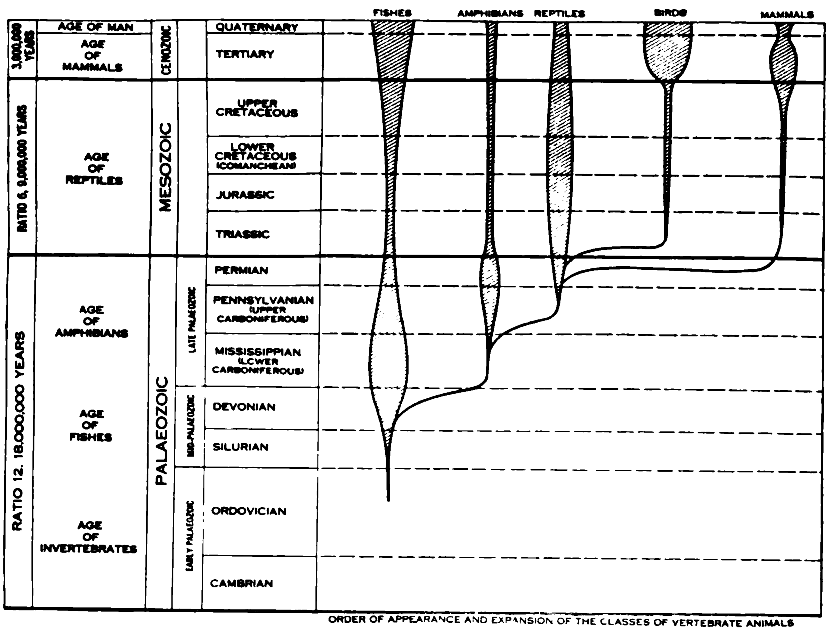

FIG. 5. ORDER OF GEOLOGIC APPEARANCE AND EPOCHS OF MAXIMUM ADAPTIVE RADIATION (EXPANSION) AND DIMINUTION (CONTRACTION) OF THE FIVE CLASSES OF VERTEBRATED ANIMALS. Prepared by Osborn and Gregory.

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FORM EVOLUTION OF THE VERTEBRATES UNDER THE MECHANICAL AND PHYSICO-CHEMICAL ACTIONS, REACTIONS AND INTERACTIONS OF LOCOMOTION, OFFENSE AND DEFENSE, AND REPRODUCTION[3]

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The form-evolution of the backboned animals, beginning with these pro-fishes of Cambrian and Pre-Cambrian time, extends over a period of 30,000,000 years. The supremely adaptable vertebrate body type begins to dominate the living world, overcoming one mechanical difficulty after another as it passes through the habitat zones of water, land and air. Motions necessary for the capture, storage and release of plant and animal energy continue to control the form of the body and of its appendages, but in the meantime the organism through mechanical and chemical means protects itself either offensively or defensively and also adapts itself to reproduce and protect its kind, according to Darwin's original conception of the struggle for existence as involving both the life of the individual and the life of its progeny. Among all defenseless forms speed is a prime necessity, while all heavily armored forms gradually abandon mobility. As among the Invertebrata, calcium carbonate and phosphate and various compounds of keratin and chitin are the chemical materials of armature. Locomotion, as distinguished from that in all invertebrates, is in an elongate body stiffened by a central axis. The evolution of the skeletal supports (endoskeletal) and limbs is generally from the center of the body (notochord) toward the periphery, the evolution of the defensive armature (exoskeleton) is from the periphery toward the center. The defensive armature finally, through change of function, makes important contributions to the inner skeleton.

THE LAW OF CONVERGENCE OR PARALLELISM IN LOCOMOTOR, OFFENSIVE AND DEFENSIVE ADAPTATIONS

Although the structural body type and mechanism of locomotion is profoundly diverse, there arise hundreds of adaptive parallels between the Vertebrata and the antecedent evolution of the Invertebrata. The combined necessity for protection and locomotion brings about close parallels in body form between such primitive Silurian eurypterids as *Bunodes* and the vertebrate Ostracoderms, a superficial resemblance which has led Patten[4] to defend the view that the two groups are genetically related.

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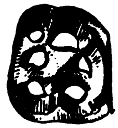

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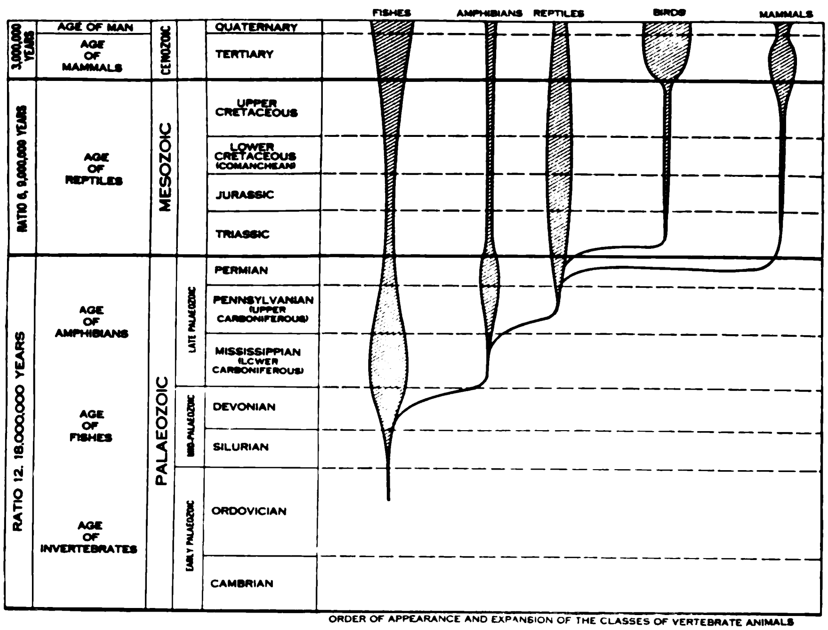

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poda) is designed chiefly to overcome the resistance of gravity and in a less degree the resistance of the atmosphere through which the body moves. When the aerial stage evolves, with increasing speed the resistance of the air becomes only slightly less than that of the water in the fish stage, and the warped surfaces, the entrant and reentrant angles evolved by the flying body are similar to those of the rapidly moving fishes.

BRANCHING OR DIVERGENCE OF FORM, THE LAW OF ADAPTIVE RADIATION

In general the *law of divergence* of form, perceived by Lamarck and rediscovered by Darwin, has been expanded by Osborn into the modern *law of adaptive radiation,* which expresses the differentiation of animal form radiating in every direction in response to the necessities of the quest for nourishment and the development of new forms of motion in the different habitat zones. *Divergence* is constantly giving rise to differences in structure, while *convergence* is constantly giving rise to resemblances of structure. In contrast with this divergent principle is the *convergence* brought about by the similarity above described of the physico-chemical laws of action, reaction and interaction and the similarity of the mechanical obstacles encountered by the different races of animals in similar habitats and environmental media.

The chief advance which has been made in the last fifty years is our abundant knowledge of the *modes* of adaptation as contrasted with the very limited knowledge yet attained as to the *causes* of adaptation. The law of adaptive radiation is a law expressing the modes of adaptation of form, which falls under the following great principles:

Law of Adaptive Radiation of Form

1. Divergent adaptation, by which the members of the primitive stock tended to develop differences of form while radiating into a number of habitat zones.
2. Convergent adaptation, whereby animals from different habitat zones enter a similar habitat zone and acquire many superficial similarities of form.
3. Direct adaptation, for example, in primary migration through an ascending series of habitat zones, aquatic or terrestrial, arboreal, aerial.
4. Reversed adaptation, where secondary migration takes the reverse direction from aerial to arboreal, to terrestrial, to aquatic habitat zones.
5. Alternate adaptation, where the animal departs from an original habitat and primary phase of adaptation, and then returns from the secondary phase of adaptation to a more or less perfect repetition of the primary phase by returning to a primary habitat zone.
6. Symbiotic adaptation, where vertebrate forms exhibit reciprocal, or interlocking adaptations with the evolution of other vertebrates or invertebrates.

reactions and interactions with each other and with the environment are heritable by the chromatin. This idea was originally suggested by the accurate observation of early naturalists and anatomists that bodily function not only controls form but is generally adaptive or purposive in its effects. According to this Lamarck-Spencer-Cope explanation a change of environment, of habit and of function should always be antecedent to changes of form in succeeding generations; moreover, if this explanation were the true one, successive changes in evolutionary series would be like growth, they would be observed to follow the direct lines of individual action, reaction and interaction, the young would be increasingly similar to the adults of antecedent generations, which is frequently the case but unfortunately for the Lamarckian explanation is not *invariably* the case.

The opposed explanation, the Darwinian, as restated by Weismann and De Vries, is that *the beginning of new form and function is to be sought in the germ cells or chromatin.* This is based upon the direct anti-Lamarckian view that the actions, reactions and interactions which cause certain bodily organs to originate, to develop, or to degenerate, to exhibit momentum or inertia in development, are not inherited and do not give rise to corresponding sets of predispositions in the chromatin. According to this explanation all predispositions to new form and function not only begin in the germ cells but are more or less lawless or experimental, they are constantly being tested or tried out by bodily experience, habits and functions. Technically stated they are fortuitous variations followed by selection of the fittest variations. Thus Darwin's disciple, Poulton, also De Vries, who has merely restated in his law of "mutation" Darwin's original principle of 1859, and Bateson, the most radical thinker of the three, hold the opinion that there is no adaptive law observed in variation but that the chromatin is continuously experimenting and that from these experiments selection guides the organism into adaptive and purposive lines.

ENVIRONMENTAL CORRELATION. ADAPTATIONS OF RESPIRATORY, OLFACTORY, VISUAL, AUDITORY, THERMAL, GRAVITY FUNCTIONS AND ORGANS

TO VARIATIONS OF LIGHT, HEAT, HUMIDITY, ARIDITY, CAUSED BY MIGRATIONS OF THE INDIVIDUAL OR OF THE ENVIRONMENT, COORDINATIVE AND CORRELATIVE

INTERNAL CORRELATION

CORRELATION AND COORDINATION OF THE INTERNAL GROWTH AND FUNCTIONS THROUGH INTERNAL SECRETIONS (ENZYMES) AND THE NERVOUS SYSTEM

ADAPTATIONS TO NUTRITION

(1) ON INORGANIC COMPOUNDS
(2) ON BACTERIA
(3) ON PROTOPHYTA, ALGAE, ETC.
(4) ON PROTOZOA
(5) ON HIGHER PLANTS, HERBIVOROUS DIET
(6) ON HIGHER ANIMALS, CARNIVOROUS DIET
(7) PARASITIC, WITHOUT OR WITHIN PLANTS AND ANIMALS

ADAPTATIONS TO INDIVIDUAL COMPETITION AND SELECTION

(A) SELECTION, AFFECTING VARIATION, RECTIGRADATION, MUTATION, ORIGIN AND DEVELOPMENT OF SINGLE CHARACTERS, PROPORTIONS, ETC
(B) AFFECTING ALL REPRODUCTIVE ORGANS, PRIMARY AND SECONDARY

ADAPTATIONS OF RACIAL COMPETITION AND SELECTION

AFFECTING CHIEFLY ALL MOTOR, PROTECTIVE OFFENSIVE, AND DEFENSIVE STRUCTURES OF THE ENDO- AND EXOSKELETON, ALSO REPRODUCTION RATE

a. The peculiar significance of vertebrate chromatin is its stability in combination with incessant plasticity and adaptability to varying environmental conditions and new forms of bodily action.

Neither the Lamarckian nor the Darwinian explanation accords

THE ORGANIZATION OF INDUSTRY AND OF SCIENTIFIC RESEARCH

In the United States, as well as in England, steps are being taken toward a more effective organization of industrial and scientific work. A Council of National Defense was established by the congress at the close of its session and the president has now announced the appointment of an advisory commission to consist of Daniel Willard, president of the Baltimore and Ohio Railroad; Samuel Gompers, president of the American Federation of Labor; Dr. Franklin H. Martin, of Chicago; Howard E. Coffin, of Detroit; Bernard Baruch, of New York; Hollis Godfrey, of Philadelphia, and Julius Rosenwald, of Chicago.

With these appointments the president gave out a statement in which he said:

> The Council of National Defense has been created because the congress has realized that the country is best prepared for war when thoroughly prepared for peace. From an economic point of view there is now very little difference between the machinery required for commercial efficiency and that required for military purposes. In both cases the whole industrial mechanism must be organized in the most effective way. Upon this conception of the national welfare the council is organized, in the words of the act, for "the creation of relations which will render possible in time of need the immediate concentration and utilization of the resources of the nation." The organization of the council likewise opens up a new and direct channel of communication and coöperation between business and scientific men, and all departments of the government, and it is hoped that it will, in addition, become a rallying point for civic bodies working for the national defense.

At the same time the National Research Council, to the plans for which attention was called in the September issue of the Monthly, has been organized under the auspices of the National Academy of Sciences. Some forty members have been appointed with Dr. George E. Hale, director of the Mt. Wilson Solar Observatory, as chairman, Dr. Cary T. Hutchinson, secretary of the Engineering Foundation, as secretary, and Dr. J. J. Carty, chief engineer of the American Telephone and Telegraph Company, as chairman of the executive committee. Special committees have been appointed to report on research in educational institutions, on the promotion of industrial research, on a national census of research, and on other subjects. The National Council is fortunate in having brought together engineers and those engaged in laboratory research, men in the industries, in the universities, in the research foundations and in the government service.

With the Naval Consulting Board we thus have three advisory councils or committees appointed under government auspices with a view to "preparedness." As the president states "the country is best prepared for war when thoroughly prepared for peace," and it would probably be wise for the Research Council of the National Academy to abandon the direct reference to war under which it was created and to confine its efforts to improving the conditions under which scientific research can be undertaken in this country, more especially in the direction of establishing fruitful relations between workers in the so-called "pure" sciences and in the industries.

In Great Britain the first annual report of the Committee of the Privy Council for Scientific and Industrial Research has been issued. The main body of the report is supplied by the advisory council of the committee, of which Sir William McCormick is chairman. After a brief account of the existing institutions for the scientific study of trade

searches on heredity each of these character complexes is now believed to have a corresponding physico-chemical determiner or group of determiners in the germ chromatin, the chromatin existing not as a miniature but as an individual *potential and causal.*

The *principle of individuality,* namely, of separate development and existence, which we have seen to be the prime characteristic of the first chemical assemblage into an organism (p. 179), also governs each of these character complexes. In some vertebrates we observe an infinity of similar character complexes evolving in an exactly similar

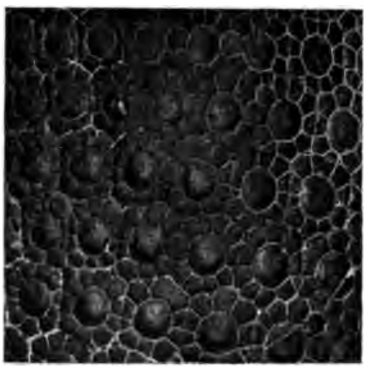
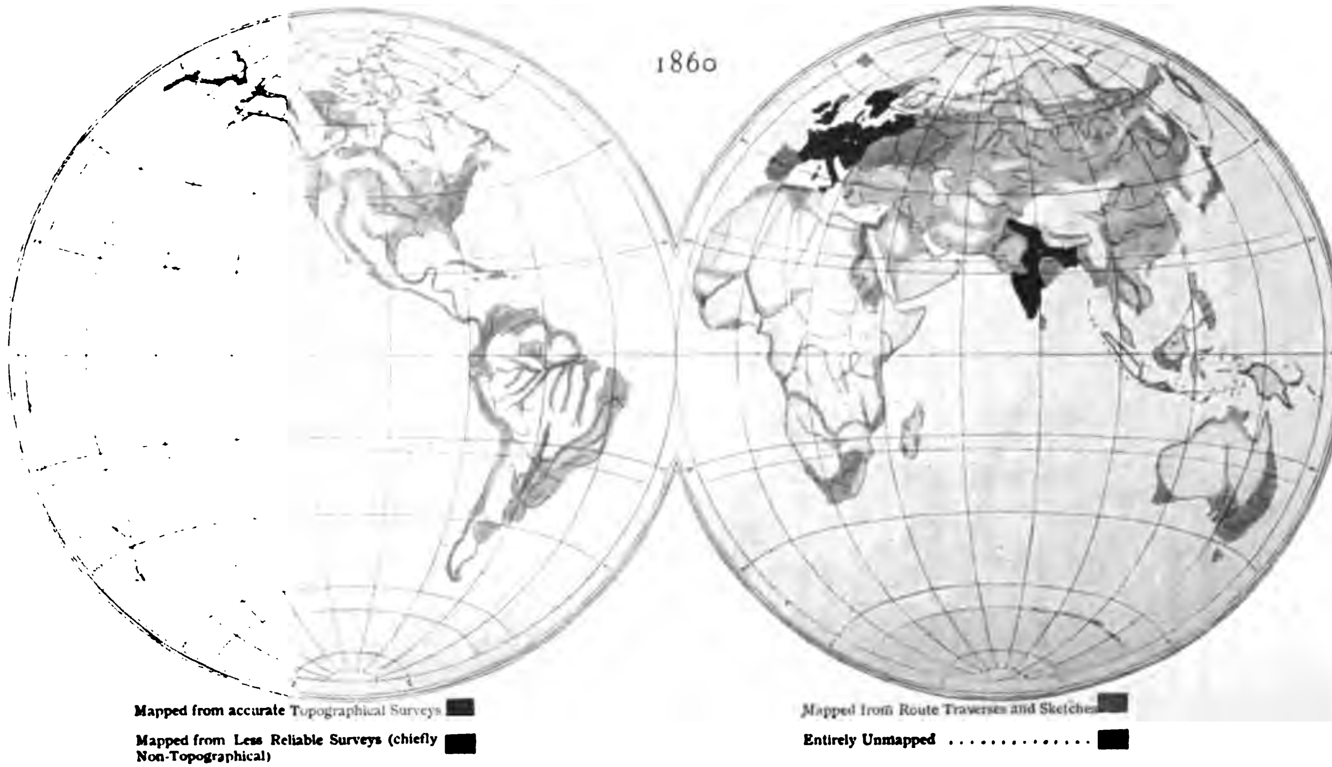


FIG. 1. SHELL.

FIG. 2. TOOTH.

manner, as in the beautiful markings of the shell and the exquisite enamel pattern of the teeth of the glyptodon, in which every portion of the shell evolves similarly, and every one of the teeth evolve similarly, from which we might conclude that there is an absence of individuality in form-characters and that some homomorphic (similarly formative) impulse is present in all characters of similar ancestry; but this rash conclusion is offset by the existence of other character complexes of similar ancestry which each evolve differently, or are in a high degree heteromorphic (diversely formative), as, for example, in the grinding teeth of mammals.

This individuality and separability inherent in character-form is equally observed in character-velocity, and is at the basis of the shifting of characters and of all the proportionate and quantitative changes which make up four-fifths of vertebrate evolution. For example, two character-forms side by side may evolve with equal velocity and maintain a perfect symmetry or one may be accelerated into very rapid



MAP OF THE EARTH. Surveys in 1860.

Changing bodily form and function and the ever changing velocity in character-complexes is to be regarded as an expression of physico-chemical energy resulting from the actions, reactions and interactions of different parts of the organism, and, as repeatedly stated in these lectures, the only vista which we enjoy at present into the causes of character-origin, character-velocity and character-cooperation is through chemical catalysis, namely, through the hypothesis that actions and reactions of form and of motion liberate specific catalytic messengers in the nature of ferments, enzymes, hormones, which produce specific and cooperating interactions in every character-complex of the organism. In our survey of the marvelous evolution of the vertebrates we may constantly keep in mind the concept of the actions, reactions and interactions of the hard parts of the structural tissues, which are preserved in fossils. In this field of observation the chemical and physiological influences of the body can only be inferred and the relations of these physico-chemical influences to those of the chromatin are absolutely unknown. Yet changes in the bodily hard parts invariably mirror the evolution of the chromatin, in fact, this evolution is nowhere revealed in a more extraordinary manner than in the incessantly changing characters in such hard parts as the labyrinthine foldings of the deep layers of enamel in the grinding teeth of the horse. This evolution of the hard parts in adaptation resolves itself into six chief and concurrent phenomena, namely:

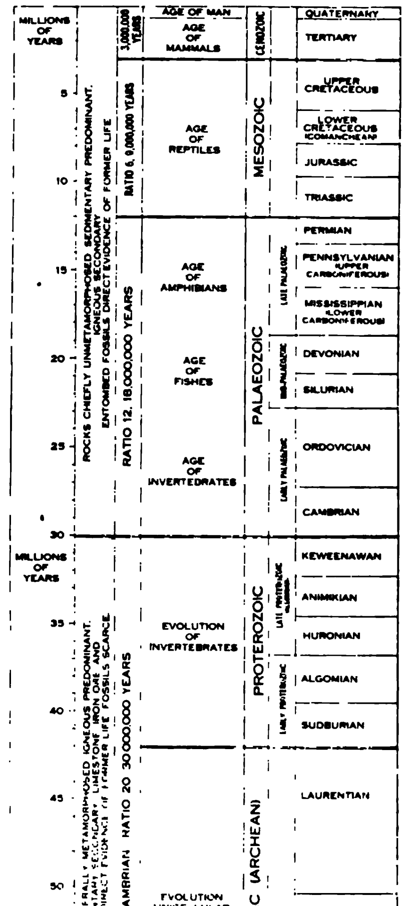


FIG. 6. GEOLOGIC TIME SCALE. Prepared by the author and C. A. Reeds after Schuchert.

acter-parallax idea has innumerable applications and can be expressed quantitatively.—W. K. GREGORY.

Courtesy of Bostonia.

ALEXANDER GRAHAM BELL AND WILLIAM FAIRFIELD WARREN.

Dr. Bell (who is shown standing) was professor of the mechanism of speech in the School of Oratory of Boston University from 1874 to 1879, while Dr. Warren was president of the university. Dr. Warren in his annual reports makes frequent reference to Dr. Bell's discovery and perfection of the telephone in 1875 and 1876. In 1878 Dr. Bell was invited to lecture at Oxford, and in his next annual report Dr. Warren says that "this is the actual initiation of a practice of international academic exchange which is destined to grow into proportions of the highest import."

quickly darting types of unarmored fishes. The double pointed, fusiform body, in which the segmented propelling muscles are external and a stiffening notochord is central, is the fish prototype, which more or less clearly survives in the existing lancelets (*Amphioxus*) and in the larval stages of the degenerate Ascidians. These animals furnish numerous embryonic and larval proofs of descent from nobler types.

Taking the whole history of vertebrate life from the beginning, we observe that every prolonged adaptive phase in a similar habitat becomes impressed in the hereditary characters of the chromatin, which throughout the development of new adaptive phases always retains more or less potentiality of repeating the embryonic, immature, and even the mature structures of older adaptive phases of older environments. The chromatin is at once the most conservative and the most progressive center of physico-chemical evolution; it records past adaptations, it meets the emergencies of the present through the adaptability which it imparts to the organism in its distribution throughout every living cell; it is continuously giving rise to new characters and functions. This law of ancestral repetition, formulated by Louis Agassiz

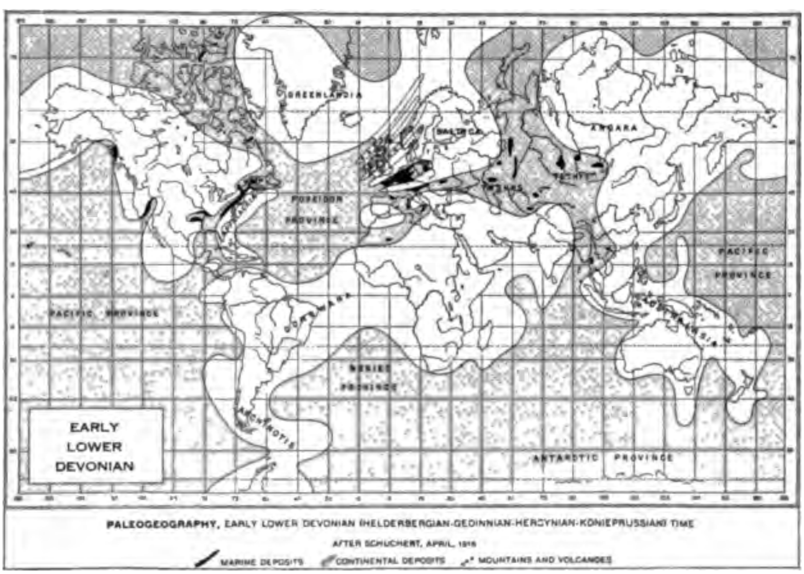


FIG. 8. PERIOD OF THE EARLY APPEARANCE OF TERRESTRIAL INVERTEBRATES AND VERTEBRATES. Paleogeography of the earth in early Lower Devonian time, showing the hypothetical southern continent *Gondwana* and the Eurasiatic inland sea *Tethys*, according to the hypotheses of Suess. After Schuchert, 1916.

and developed by Haeckel and Hyatt, dominated biological thought during thirty years of the nineteenth century (1865–1895), and with more or less success a highly speculative solution of the ancestral history of the vertebrates was sought in embryonic development and com-

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Physical environment, succession, reversal and alternation of habitat zones,	**Incessant**
Individual development, succession, reversal and alternation of adaptive phases,	**Selection**
Chromatin evolution, addition of the determiners of new adaptations while preserving the determiners of old adaptations,	**and**
Succession of life environments.	**Competition**

Yet it must be the similarity of these internal physico-chemical energies of protoplasm and the similarity in the mechanics of motion, of offense and defense, which underlies the law of convergence or parallelism in adaptation, namely, *the production of externally similar forms in adaptation to externally similar natural forces,* a law which escaped the keen observation of Huxley[5] in his remarkable analysis of the modes of vertebrate evolution published in 1880.

The whole process of motor adaptation in the vertebrates, whether the fishes, amphibians, reptiles, birds, or mammals, is the solution of a series of mechanical problems, adjustment to gravity, overcoming the resistance of water or air in the development of speed; in the evolution of the limbs of creating levers, fulcra (joints) and pulleys. The fore and hind fins of fishes and the fore and hind feet of mammals evolve uniformly where they are homodynamic and divergently where they are heterodynamic. This principle of homodynamy and heterodynamy applies to the body as a whole and to every one of its parts, according to two laws: first, that each individual part has its own mechanical evolution, and, second, that the same mechanical problem is generally solved on the same principle. This we observe is invariably the ideal principle, for unlike man nature wastes little time on inferior inventions but immediately proceeds to superior inventions.

The three mechanical problems of existence in the water habitat are: first, overcoming the buoyancy of water either by weighting down, increasing the gravity of the body, or by the development of special gravitating organs which enable animals to rise and descend in this medium; second, the mechanical problem of overcoming the resistance of water in rapid motion which is accomplished by means of warped surfaces and well-designed entrant and reentrant angles of the body similar to those of the fastest modern yachts; third, the problem of propulsion of the body, which is accomplished, first, by sinuous motion of the entire body terminating in the powerful propulsion of the tail fin, secondly, by supplementary action of the four lateral fins, third, by the horizontal steering of the body by means of the median system of fins.

[5] Huxley, T. H., "On the Application of the Laws of Evolution to the Arrangement of the Vertebrata, and more Particularly of the Mammalia," *Proc. Scientific Meetings of the Zoological Soc. of London for the year 1880,* pp. 649–662. (Read December 14, 1880.)

poda) is designed chiefly to overcome the resistance of gravity and in a less degree the resistance of the atmosphere through which the body moves. When the aerial stage evolves, with increasing speed the resistance of the air becomes only slightly less than that of the water in the fish stage, and the warped surfaces, the entrant and reentrant angles evolved by the flying body are similar to those of the rapidly moving fishes.

BRANCHING OR DIVERGENCE OF FORM, THE LAW OF ADAPTIVE RADIATION

In general the *law of divergence* of form, perceived by Lamarck and rediscovered by Darwin, has been expanded by Osborn into the modern *law of adaptive radiation,* which expresses the differentiation of animal form radiating in every direction in response to the necessities of the quest for nourishment and the development of new forms of motion in the different habitat zones. *Divergence* is constantly giving rise to differences in structure, while *convergence* is constantly giving rise to resemblances of structure. In contrast with this divergent principle is the *convergence* brought about by the similarity above described of the physico-chemical laws of action, reaction and interaction and the similarity of the mechanical obstacles encountered by the different races of animals in similar habitats and environmental media.

The chief advance which has been made in the last fifty years is our abundant knowledge of the *modes* of adaptation as contrasted with the very limited knowledge yet attained as to the *causes* of adaptation. The law of adaptive radiation is a law expressing the modes of adaptation of form, which falls under the following great principles:

Law of Adaptive Radiation of Form

1. Divergent adaptation, by which the members of the primitive stock tended to develop differences of form while radiating into a number of habitat zones.
2. Convergent adaptation, whereby animals from different habitat zones enter a similar habitat zone and acquire many superficial similarities of form.
3. Direct adaptation, for example, in primary migration through an ascending series of habitat zones, aquatic or terrestrial, arboreal, aerial.
4. Reversed adaptation, where secondary migration takes the reverse direction from aerial to arboreal, to terrestrial, to aquatic habitat zones.
5. Alternate adaptation, where the animal departs from an original habitat and primary phase of adaptation, and then returns from the secondary phase of adaptation to a more or less perfect repetition of the primary phase by returning to a primary habitat zone.
6. Symbiotic adaptation, where vertebrate forms exhibit reciprocal, or interlocking adaptations with the evolution of other vertebrates or invertebrates.

alterations in the chromatin, and in consequence the history of past phases is more or less clearly recorded. It is very important to keep in mind that the body and limb form developed in each adaptive phase is the starting point of the next succeeding phase.

Among the disadvantages of prolonged zonal existence are the following. Through the law of compensation, discovered by Geoffroy St. Hilaire early in the last century, every vertebrate in developing and specializing certain organs sacrifices others; for example, the lateral digits of the foot of the horse are sacrificed for the evolution of the central digit as the animal evolves from tridactylism to monodactylism. These sacrificed parts are never regained; the horse can never revert to the tridactyl condition although it might reenter the habitat zone in which three digits on each foot would serve the purposes of locomotion better than one. In this sense chromatin evolution is irreversible. The extinction of vertebrate races has generally been due to the fact that the various types have sacrificed too many characters in their physiological reactions to a particular life habitat zone. A finely specialized form representing a perfect mechanism in itself which closely interlocks with its physical and living environment reaches a *cul de sac* of structure from which there is no possible emergence by adaptation to a different physical environment, or habitat zone. It is these two principles of the non-revival of characters once lost by the chromatin and of too close adjustment to a single environment which underly the law that the highly specialized and most perfectly adapted types become extinct, while primitive, conservative and relatively unspecialized types invariably become the centers of new adaptive radiations.

HABITAT MIGRATIONS OF THE INDIVIDUAL

MIGRATIONS OF THE ENVIRONMENT

AËRIAL
(FLYING, VOLANT, TYPES)

AËRO-ARBOREAL
(PARACHUTE, GLISSANT, TYPES)

ARBOREAL
(CLIMBING, LEAPING, BRACHIATING TYPES)

ARBOREO-TERRESTRIAL
(WALKING AND CLIMBING, SCANSORIAL, TYPES)

TERRESTRIAL
(AMBULATORY, SLOW; CURSORIAL, RAPID; SALTATORY, LEAPING; GRAVIPORTAL, SLOW, CUMBROUS. MUTIPEDAL, QUADRUPEDAL, BIDEDAL, APODAL, ETC.)

TERRESTRIO-FOSSORIAL
(WALKING AND BURROWING TYPES)

FOSSORIAL
(BURROWING TYPES)

TERRESTRIO-AQUATIC
(AMPHIBIOUS TYPES)

AQUATIC
(SURFACE-LIVING, BOTTOM-LIVING, SWIFT-CURRENT, SLOW-CURRENT)

FLUVIATILE
(FRESHWATER, FLUVIO-MARINE TYPES)

LITTORAL
(SURFACE AND FOSSORIAL TYPES)

PELAGIC
(FREE SURFACE-LIVING, DRIFTING, FLOATING, SELF-PROPELLING TYPES)

ABYSSAL
(DEEP BOTTOM-LIVING TYPES. SLOW AND SWIFT-MOVING)

b. THE THIRTEEN CHIEF VERTEBRATE HABITAT ZONES, each of which is divided into many subzones.

(*To be continued*)

THE ORGANIZATION OF INDUSTRY AND OF SCIENTIFIC RESEARCH

In the United States, as well as in England, steps are being taken toward a more effective organization of industrial and scientific work. A Council of National Defense was established by the congress at the close of its session and the president has now announced the appointment of an advisory commission to consist of Daniel Willard, president of the Baltimore and Ohio Railroad; Samuel Gompers, president of the American Federation of Labor; Dr. Franklin H. Martin, of Chicago; Howard E. Coffin, of Detroit; Bernard Baruch, of New York; Hollis Godfrey, of Philadelphia, and Julius Rosenwald, of Chicago.

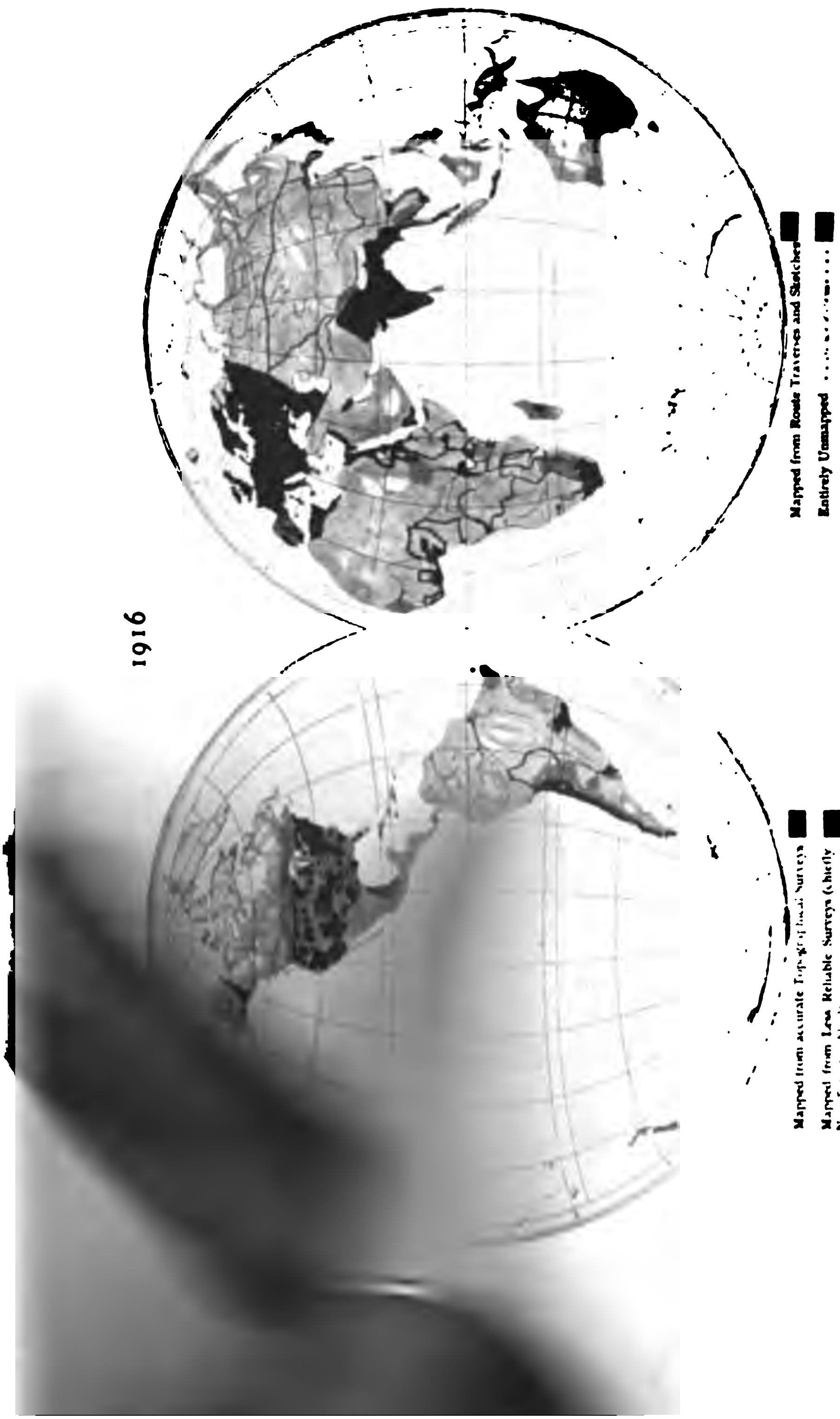
With these appointments the president gave out a statement in which he said:

> The Council of National Defense has been created because the congress has realized that the country is best prepared for war when thoroughly prepared for peace. From an economic point of view there is now very little difference between the machinery required for commercial efficiency and that required for military purposes. In both cases the whole industrial mechanism must be organized in the most effective way. Upon this conception of the national welfare the council is organized, in the words of the act, for "the creation of relations which will render possible in time of need the immediate concentration and utilization of the resources of the nation." The organization of the council likewise opens up a new and direct channel of communication and coöperation between business and scientific men, and all departments of the government, and it is hoped that it will, in addition, become a rallying point for civic bodies working for the national defense.

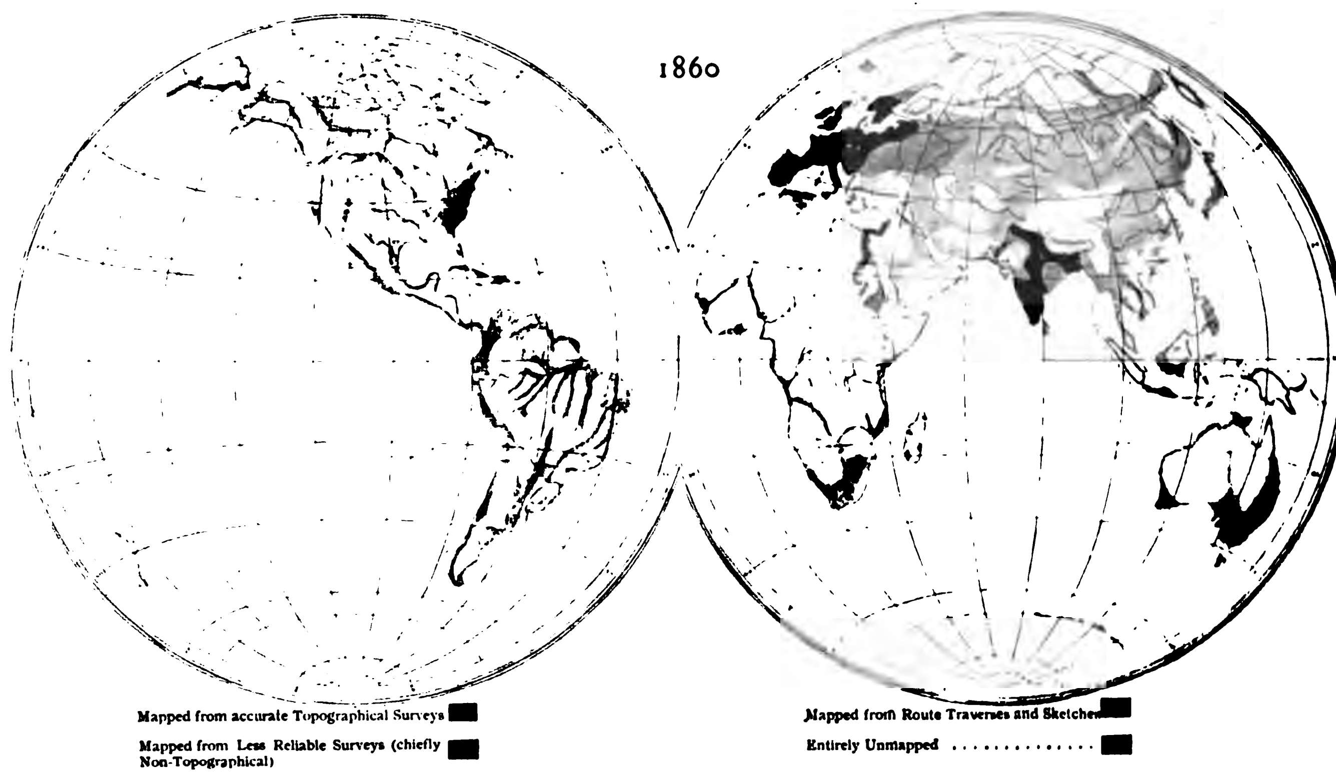
At the same time the National Research Council, to the plans for which attention was called in the September issue of the MONTHLY, has been organized under the auspices of the National Academy of Sciences. Some forty members have been appointed with Dr. George E. Hale, director of the Mt. Wilson Solar Observatory, as chairman, Dr. Cary T. Hutchinson, secretary of the Engineering Foundation, as secretary, and Dr. J. J. Carty, chief engineer of the American Telephone and Telegraph Company, as chairman of the executive committee. Special committees have been appointed to report on research in educational institutions, on the promotion of industrial research, on a national census of research, and on other subjects. The National Council is fortunate in having brought together engineers and those engaged in laboratory research, men in the industries, in the universities, in the research foundations and in the government service.

With the Naval Consulting Board we thus have three advisory councils or committees appointed under government auspices with a view to "preparedness." As the president states "the country is best prepared for war when thoroughly prepared for peace," and it would probably be wise for the Research Council of the National Academy to abandon the direct reference to war under which it was created and to confine its efforts to improving the conditions under which scientific research can be undertaken in this country, more especially in the direction of establishing fruitful relations between workers in the so-called "pure" sciences and in the industries.

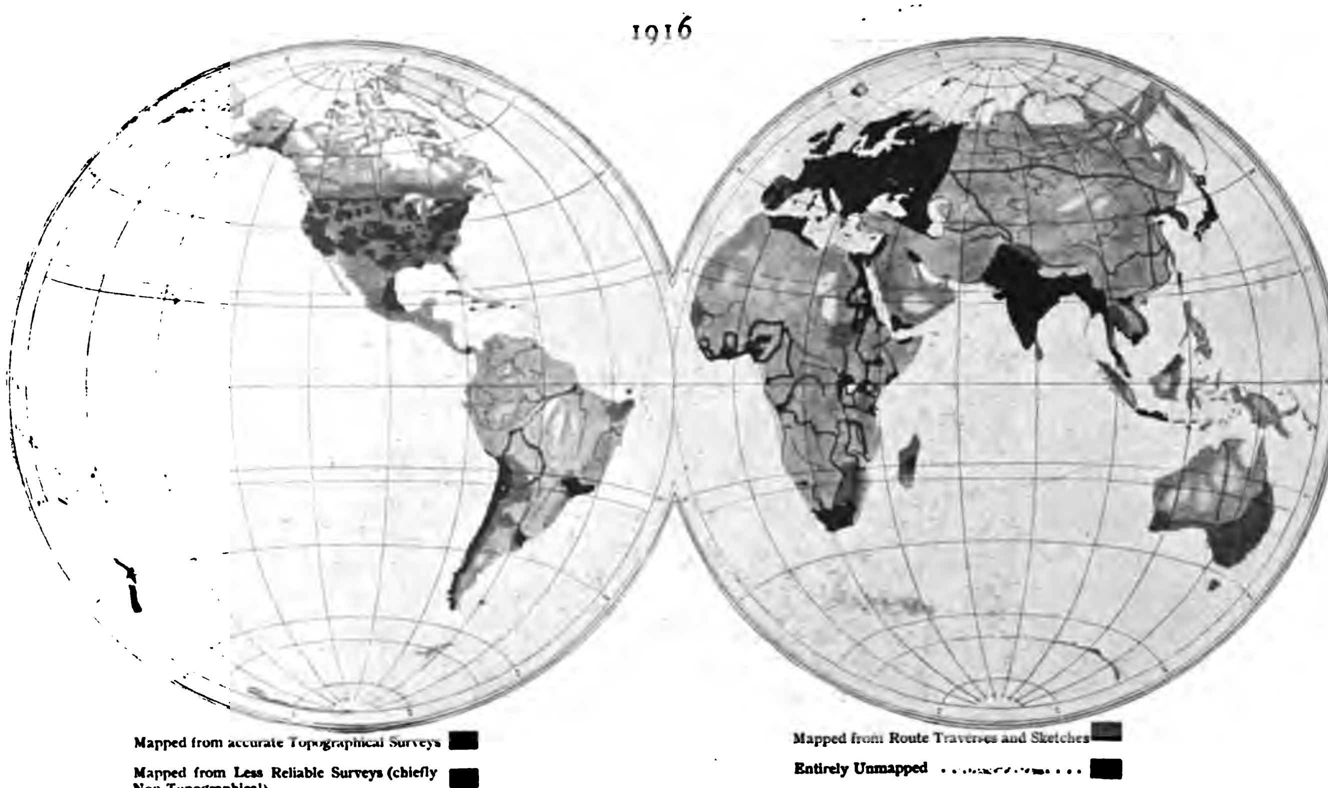
In Great Britain the first annual report of the Committee of the Privy Council for Scientific and Industrial Research has been issued. The main body of the report is supplied by the advisory council of the committee, of which Sir William McCormick is chairman. After a brief account of the existing institutions for the scientific study of trade



MAP OF THE EARTH. Surveys in 1916.



MAP OF THE EARTH. Surveys in 1860.



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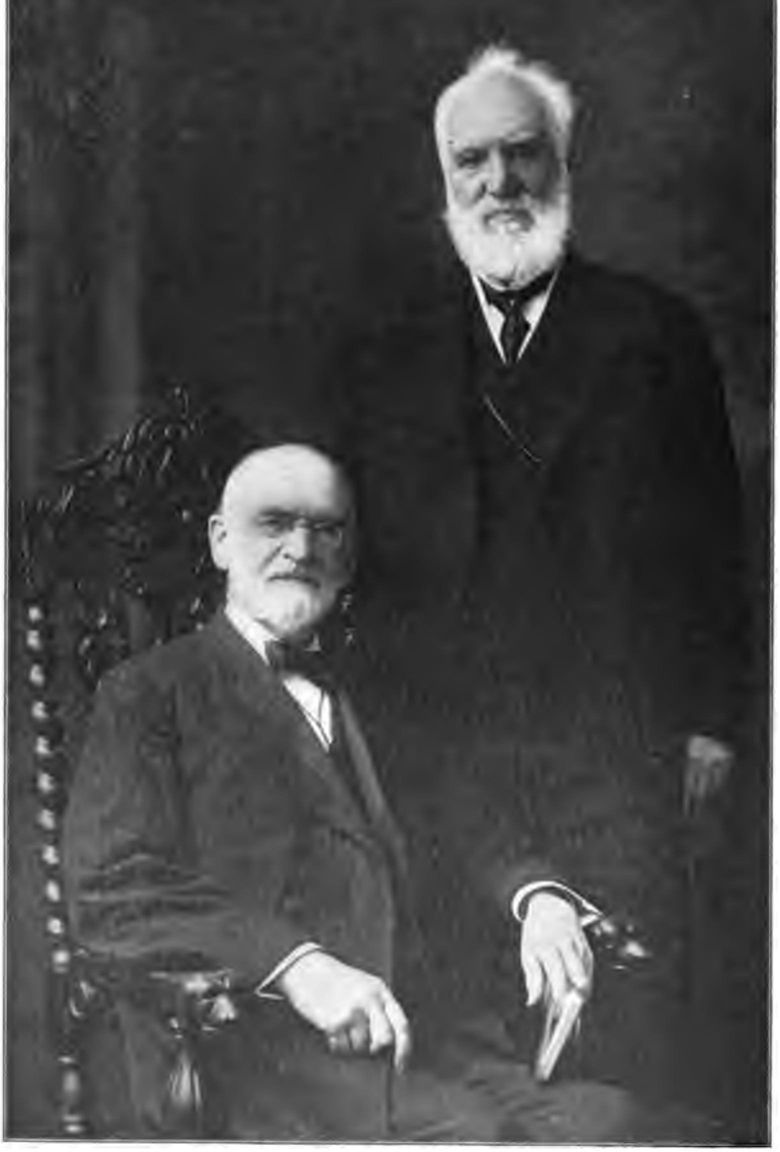

Courtesy of Bostonia.

ALEXANDER GRAHAM BELL AND WILLIAM FAIRFIELD WARREN.

Dr. Bell (who is shown standing) was professor of the mechanism of speech in the School of Oratory of Boston University from 1874 to 1879, while Dr. Warren was president of the university. Dr. Warren in his annual reports makes frequent reference to Dr. Bell's discovery and perfection of the telephone in 1875 and 1876. In 1878 Dr. Bell was invited to lecture at Oxford, and in his next annual report Dr. Warren says that " this is the actual initiation of a practice of international academic exchange which is destined to grow into proportions of the highest import."

Europe, where a considerable extent of accurate surveying had been carried out, the only country where any mapping, based upon triangulation, had been done was India. These areas are shown in the darkest shading. In Europe, France, British Isles, Germany, Austria, Italy, Russia, Switzerland, Denmark, the Netherlands, and Scandinavia had already made a good commencement with their government maps based upon trigonometrical surveys, but these were in several cases by no means complete. India has been noted for the excellency of its surveys ever since the days of Major Lambton, who started the work in 1804, and Colonel Everest, who succeeded him as head of the surveys after Lambton's death in 1823.

In the parts of the Eastern Hemisphere that were surveyed and mapped in the second degree of accuracy, that is, those shown by the next tint, may be included most of the remaining parts of Europe, Egypt, and parts of Algeria near the coast. For the rest such mapping as was done was based upon rough route-sketches, shown by the third tint. In this must be included practically all that was known of the African continent, such as the explorations of Mungo Park, Beke, Livingstone, Speke and Grant, and others, as well as the early exploratory surveys in Central Asia and Australia. The regions that were entirely unsurveyed and unmapped at this time were enormous in their extent, and included not only the Polar regions, but vast areas of Central Africa, Asia and Australia.

Turning to the Western Hemisphere, we find that at this date no triangulation of any extent had been carried out. The U. S. Coast and Geodetic Survey had made a good start, but their work had been confined to the coastline or districts near the coast. There had been La Condamine's attempt at measuring an arc of the meridian near Quito in South America in 1736, the measurement of the Mason and Dixon line, and their survey of the boundary between Pennsylvania and Maryland, in the latter part of the same century; but neither of these resulted in any serious topographical mapping. Such surveys as existed of the interior parts of the United States in 1860, although they varied as regards their merits and degree of dependence, could not be considered as anything but approximate. Some parts of the eastern states are shaded with a tint of the second density, but, with this exception, such mapping as had been done either in North or South America can not be considered of a higher order than route-traversing and sketching, and is tinted accordingly.

Referring now to the 1916 map on which the same shades of tints have the same meaning as on the previous map, the parts that are accurately surveyed from a topographical point of view, based upon triangulation or rigorous traverses, have greatly increased in extent, and these now represent about one seventh of the total area of the land-surface of the earth, instead of only one thirtieth, as was the case in 1860. Remarkable progress has also been made with regard to both of the less accurate kinds of surveying and mapping, while

	1860 Sq. Stat. Miles Proportion to Whole	1916 Sq. Stat. Miles Proportion to Whole
Mapped from accurate topographical surveys based on triangulation or rigorous traverses	1,957,755 = 0.0326 or roughly 1/30	8,897,238 = 0.1482 or roughly 1/7
Mapped from less reliable surveys, chiefly non-topographical	2,017,641 = 0.0336 or roughly 1/30	5,178,008 = 0.0866 or just over 1/12
Mapped from route traverses and sketches	25,024,360 = 0.4170 or roughly 2/5	37,550,552 = 0.6258 or little less than 2/3
Entirely unsurveyed and unmapped	30,997,054 = 0.5166 or just over 1/2	8,350,794 = 0.1391 or little less than 1/7

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An estimate of the condition of the world's surveys as represented by the differently tinted areas on the maps for 1860 and 1916, taking the total area of the land-surface of the earth together with the unknown parts of the Arctic and Antarctic regions which may be either land or water, to be 60,000,000 square miles, gives in square miles the results shown on page 519.

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Vol. 3, No. 6 DECEMBER, 1916

THE SCIENTIFIC MONTHLY

EDITED BY J. McKEEN CATTELL

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THE SCIENCE PRESS

LANCASTER, PA. GARRISON, N. Y.

NEW YORK: SUB-STATION 84

SINGLE NUMBER, 30 CENTS YEARLY SUBSCRIPTION, $3.00

THE SCIENTIFIC
MONTHLY

DECEMBER, 1916

WHAT WE KNOW ABOUT COMETS[1]

By Dr. W. W. Campbell

DIRECTOR OF THE LICK OBSERVATORY, UNIVERSITY OF CALIFORNIA

THE startlingly sudden appearance of some great comets, the rapid growth of others to enormous sizes and their equally rapid disappearance have naturally excited the interest and, only too often, the fears of the human race. We are removed less than two centuries from the long-prevailing theological view that comets are flaming fire-balls hurled at the earth by an angry God, to frighten and punish a sinful world. Up to the time of my childhood the opinion was widespread among civilized peoples that comets are the forerunners of famine, pestilence and war. Did not the great comet of 1811 herald the war of 1812; the comet of 1843 the war of 1846; and Donati's comet of 1858 our Civil War? Even in the twentieth century the fear that a comet may collide with the earth and destroy its inhabitants comes to the surface, here and there, every time a comet is visible to the naked eye. This fear is not lessened by the highly sensational descriptions of such encounters by professional writers who have that little knowledge which has been called a dangerous thing.

The earth has undoubtedly encountered comets' tails scores and scores of times since the advent of man, and with no baneful effects; and in the light of present-day knowledge of the structure and chemical composition of comets there is no danger whatever that our atmosphere will be poisoned by such an encounter. It is true that a collision between the earth and the head of a comet *could* happen, but we see no reason to question the accuracy of the estimates made by mathematical astronomers that such encounters will not occur more than once in fifteen or twenty million years, on the average! It is by no means certain that such an encounter, should one ever occur, would be a serious matter for the earth. Its effects might be confined to a brilliant shower of meteors, such as the peoples of the earth have observed many times. Geologists are of the opinion that the outcropping strata

[1] Retiring address of the first president of the Pacific Division of the American Association for the Advancement of Science. San Diego, August 9, 1916.

of approximately 100 million years for their formation. These strata, embracing the entire land area of the earth, have given only one bit of evidence that the earth's surface has been affected by a collision with an outside body. In central Arizona is a cup-shaped hole-in-the-ground, about three quarters of a mile in diameter and several hundred feet deep which has been formed, with little doubt, by the descent of a great meteorite, or of a great cluster of small meteorites: thousands of small iron meteorites have been found in and around the hole, and there are no evidences of volcanic activity in the neighborhood. Geologic and geographic surveys of the earth have revealed no other case of collisional effects[2] in the records of a hundred million years. Man himself has lived upon the earth certainly many tens of thousands of years, and there are no traditions extant concerning injuries to earth or to man from comets. Why then should anybody worry about possible injury from a comet in his short span of three score years and ten?

The answer to our first question, where do comets come from, involves the question of their relationship to the solar system and to the great stellar system. It is essential that every auditor should understand certain prominent features of the solar and stellar systems; and, at the risk of repeating what many members of the audience already know, I shall devote a few lines to a description of these systems.

Widely scattered throughout a great, but finite, volume of space occupied by our stellar system are tens of millions of stars. It is estimated that our largest refracting telescopes could show us about seventy million stars, and that the reflecting telescopes could photograph possibly two or three times as many. Our own sun is just one of these scores of millions of stars. It seems very large, very bright and very hot because we on the earth are relatively close to it. It is our own star. Revolving around it are many planets, of which our earth is one. Probably the other stars in many cases, possibly in all cases, have planets revolving around them in the same way. We do not know that this is a fact because the nearest star, excepting our own star, is so far away that we should require telescopes at least twenty-five feet in diameter to see planets revolving about it, even though such planets be as large as Jupiter and Saturn, the largest planets revolving around the sun.

Now the sun and its planets and their moons are the chief members of an orderly system which we call the solar system. Ninety-nine and six sevenths per cent. of all the materials in the solar system is in the sun, and only one seventh of one per cent. is divided up to form the planets and their moons: Mercury, Venus, the Earth and its one moon, Mars and its two moons, the more than 800 minor planets which move

[2] Neglecting the insignificant cavities produced by isolated small meteorites.

in the zone lying just outside the orbit of Mars, the giant planet Jupiter and its nine moons, the planet Saturn with its ring system and its nine moons, the planet Uranus and its four moons, and the outermost-known planet Neptune and its one moon.

It is a most interesting fact that all of these planets revolve around the sun in the same direction, which astronomers have agreed to call from west to east, or in the "direct" sense. Motion from east to west is called "retrograde."

Another remarkable fact is this: the orbits of all these bodies lie nearly in the same plane. If we call the distance from the sun to the earth unity, then the distance from the sun to the outermost planet, Neptune, on the same scale is thirty units, and the diameter of the solar system on that scale is sixty units. If we had a great box sixty such units in diameter and only one unit in thickness the solar system could be placed within this box and all of the eight major planets and their moons and nearly all of the minor planets would perform their motions within the box. A few of the minor planets would dip a little out of the box, above or below.

The solar system is very completely isolated in space. If the distance from the sun to the earth is one and from the sun to Neptune thirty, then the distance to the next nearest star of which we have any knowledge, Alpha Centauri, is 275,000. A ray of light traveling with a speed of 186,000 miles per second would travel from the sun to the earth in eight and one third minutes, to Neptune in four and a half hours, but it would require four and a half years to reach the sun's nearest neighbor, Alpha Centauri. The stars in the great stellar system are distributed more or less irregularly, but their average distance apart is of the order of six or seven or eight light years.

All of the stars are in motion, and our own star, the sun, is no exception to the rule. It is one of the well-established facts of astronomy that our solar system is traveling through space in the general direction of the boundary line between the constellations Lyra and Hercules with a speed of approximately twelve and one half miles per second.

It is well known that the orbits of our planets are ellipses which do not differ greatly from the circular form. The comets, on the other hand, move in very elongated orbits around the sun. The orbits of some comets are easily recognized as ellipses, but for the great majority of comets the orbits differ but little from the parabolic form. The parabola, as many of you know, is on the dividing line between ellipses and hyperbolas. The ellipse is a closed curve, and a comet moving around the sun in an elliptic orbit should return again and again to the neighborhood of the sun; but a comet following a parabolic or hyperbolic path, subject merely to the attraction of the sun, can pass through the vicinity of the sun only once, for the parabola and hyper-

proaches the sun and the branch upon which the comet recedes from the sun never come together, no matter how far out from the sun they be drawn.

There have been two hypotheses as to where the comets come from. Sir Isaac Newton thought of them as moving in elongated ellipses. It

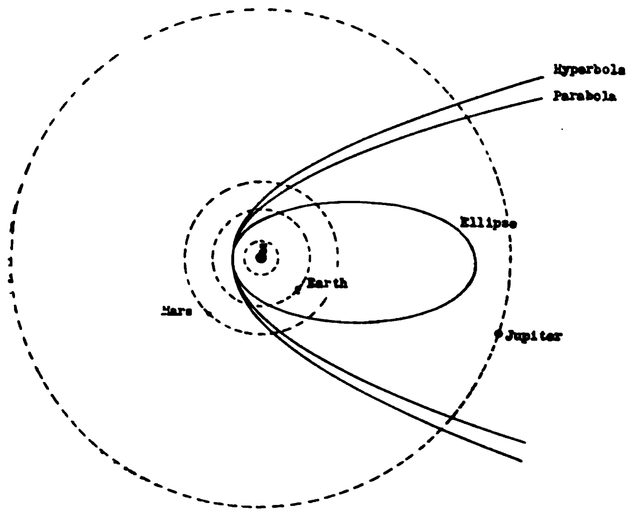


FIG. 1. CHARACTERISTIC FORMS OF ORBITS.

was the view of Immanuel Kant 160 years ago that comets are bona fide members of the solar system, just as the earth and Neptune are: that their orbits are all ellipses, but very elongated ellipses. He said that the comets travel out a great distance from the sun, but that they must eventually return because they are moving in ellipses. Kant's view of the subject was essentially a mere opinion, though the opinion of one of the greatest philosophers of all time, who gave careful consideration to every known fact. Up to Kant's day, and for many decades later, comet observations were crude in comparison with present-day standards. Most comets were observed for only a few weeks, and the true characters of their orbits could not be affirmed.

Half a century later the great Laplace championed the view that the comets belong to the stellar system and not to the solar system; that comets are travellers through interstellar space; that the wanderings of a chance few comets bring them within the sphere of influence of our sun; and that we see those which come into favorable position near the earth. Halley's celebrated comet was the only one then known to return again and again to the region of the sun, and it was thought to be a captured wanderer. In Laplace's time also the comets were still inaccurately observed, over short periods of time, and in nearly

every case a parabola seemed to represent their motion satisfactorily. This Laplacean view that comets are wanderers through the great stellar system and are only chance visitors to the solar system was the prevailing one throughout the nineteenth century. Evidences to the contrary began to appear as early as 1860, but so firmly rooted was the hypothesis that only in the twentieth century have astronomers in general been convinced that the comets are members of the solar system. Several lines of evidence, all in good agreement, have brought us to this conclusion.

1. Since the solar system is traveling through the stellar system in the direction of the constellations Lyra and Hercules, with a speed of twelve and a half miles per second, if comets come in from interstellar space we should *meet* more comets coming from the Lyra-Hercules direction than there are comets *overtaking* us from the opposite part of the sky, for precisely the same reason that if we are traveling very rapidly by automobile from San Diego to Los Angeles we should meet more autos than would overtake us and pass us. Now the comets do not show that preference. As early as 1860 Carrington studied the directions of approach of all the comets, 133 in number, which up to that time were considered to have parabolic or hyperbolic orbits. He found that only sixty-one[3] of these comets met the solar system, so to speak, whereas seventy-two[3] comets overtook us—extremely strong evidence that the comets are traveling along with us, just as all of our planets are traveling with the sun while revolving around it. Many later astronomers, especially Fabry, using the more plentiful and more accurate data now available, have confirmed this conclusion that there is no tendency for comets to meet us, as we rush through interstellar space, rather than to overtake us. It is a fact, however, that the observed comets have not had their directions of approach distributed uniformly over the surface of the sphere. Their deviations from reasonable uniformity appear to be due in small measure to a preference of comets to travel in planes making small angles with the ecliptic, with motion around the sun from west to east as in the case of the planets; but the chief discrepancies arise from the heterogeneous circumstances under which comets are discovered.

Nearly all discoveries of comets made by means of telescopes prior to forty years ago were made in the northern hemisphere, at observatories situated in latitudes north of $+40°$. The southern hemisphere is still very much in arrears in the matter of comet discoveries, though the discrepancy is not now so great as it once was.

There is more searching for comets in the northern hemisphere during the northern summer and in the southern hemisphere during the southern summer than in their respective winters. There is also

[3] The disparity in the numbers is thought to be purely accidental.

is farthest north in June and for southern observers when the sun is farthest south in December. These facts lead to the discovery of comets, prevailingly, which come to perihelion in certain favored regions; that is, in the regions of the sky where the earth is at those times.

It is advantageous at this point to call attention to other sources of lack of homogeneity in comet data.

Prior to the invention of the telescope, three centuries ago, about 400 comets had been made matters of historical record. These were naked-eye objects which forced themselves upon the attention of observers. They were the especially large comets which came close to the earth or to the sun. They were imperfectly observed, and for only a small proportion of them do we know even their approximate orbits.

Since the invention of the telescope, about 450 comets have been discovered, and the half of these have been found in the last fifty years. What we may call the golden age of comet discovery included the two decades, 1888 to 1908, when 100 comets, an average of five per year, were discovered. Four American observers, Swift, Brooks, Barnard and Perrine, announced the arrival of thirty-seven of these 100 comets.

All of the early comets were visible to the naked eye. Only a small fraction of recent comets, perhaps one in four, become bright enough for the unassisted eye to see the head, and perhaps one in eight or ten for the unassisted eye to see the tail. Comet orbits have become increasingly accurate, partly because of greater telescopes, which enable these bodies to be more accurately observed and observed through longer arcs of their orbits.

2. Another decisive argument for the theory that comets are at home in the solar system is this: Schiaparelli showed in the early '70's that, owing to the sun's motion through the stellar system, if the comets come from distant interstellar space, a very large proportion of them should move around our sun in hyperbolic orbits, and many of these orbits should be *strongly* hyperbolic. Schiaparelli's conclusions have been confirmed and extended by several mathematical astronomers, notably by Louis Fabry. Fabry concluded: If the sun travels through the stellar system and the comets come to the sun from interstellar space, then the comets should all move in hyperbolas—differing from the parabola the more as the velocity of the sun through space is the greater.

What are the facts of observation? Of 347 comet orbits fairly well determined

(*a*) 60 are certainly elliptic;
(*b*) 275 are approximately parabolic;

(*c*) 12 or fewer are slightly hyperbolic;
(*d*) None are strongly hyperbolic.

Now it has been shown by Thraen, Fayet and Fabry in the last two decades that several of the twelve orbits thought to be hyperbolic were not really so, but that they owed their reputations to poor or insufficient observations, or to errors in the computations, and that all of the genuine hyperbolas save one acquired their hyperbolicity after the comets concerned came under the disturbing influences of our planets. Five years ago Strömgren was able to show that the one outstanding hyperbolic orbit was caused, in the same way, by the disturbing attractions of the planets. The original, undisturbed orbit of every one of the so-called hyperbolic comets was, therefore, an ellipse. Fayet has further shown that a very great majority of the orbits which had been observed to be sensibly parabolic when the comets were near the planets and sun were clearly elliptic when the comets were still far out from the sun; that is, as these comets, moving in elliptic orbits, came in toward the planets and sun, the attractions of the planets made their orbits approach closely to the parabolic form. There is no reason to doubt that far out in the domain of the sun the comets all approach in elliptic orbits; but that when the attractions of one or more of our planets upon them become appreciable, some of the orbits are changed into shorter ellipses, others are changed into ellipses so long that it is difficult to distinguish them from parabolas, and many orbits are changed to the hyperbolic form. Those comets whose orbits are thus thrown into the hyperbolic form will leave the solar system and travel out through the stellar system.

3. A statistical study of comet orbits made by Leuschner a decade ago bears upon this question. He found that prior to 1755 ninety-nine per cent. of all comets were *said* to move in parabolic orbits, but that only fifty-four per cent. of comets between 1846 and 1895 were *said* to move in orbits approximately parabolic; and, secondly, that of comets under observation less than 100 days, sixty-eight per cent. were *said* to be parabolas, whereas of those observed from eight months to seventeen months, only thirteen per cent. have orbits approximately parabolic. These facts point to the conclusion that when comets are observed inaccurately, as of old, and in only a short section of their orbits, parabolic orbits satisfy the observations within the limits of the errors unavoidably attaching to those observations; but that when comets are observed accurately and for a long stretch of time, nearly all are found to be moving in ellipses. Most of the ellipses are of course extremely long ones.

If comets starting substantially at rest came from a very great distance away from our sun, say one hundredth the distance of the nearest star, which we think is decidedly within the sphere of our sun's attrac-

to distinguish them from parabolas. Their periods of revolution would be nearly one hundred and fifty thousand years. Yet they would be members of our solar system, subject to the sun's attraction, and unless disturbed by some other body or bodies, they would return again and again to the center of the system.

The work of Carrington, Schiaparelli, Fabry, Fayet, Strömgren and Leuschner and of many others has left no room for doubt that comets are bona fide members of our solar system. The materials composing the great majority of comets spend most of their time in regions far removed from the sun and its planets, as our little distances in the planetary system go, but close to the sun in terms of the magnificent distances which separate our sun from the other suns. They are moving in closed orbits around our sun and traveling through space along with our sun.[4]

Besides the comets which go out on extremely elongated orbits to great distances from the sun, there are about fifty elliptic comets which

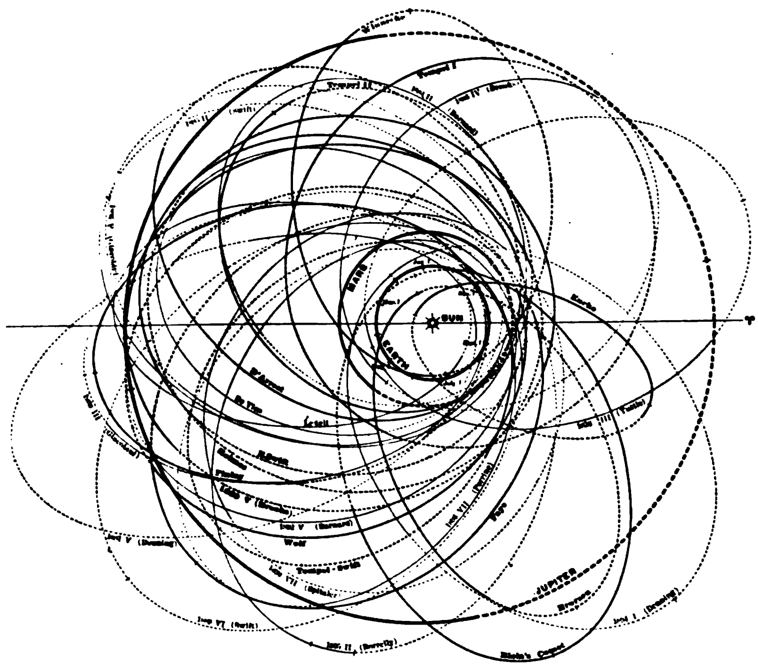


FIG. 2. JUPITER'S FAMILY OF COMETS (up to 1893).

[4] Those who would like to look more thoroughly into this question are strongly advised to read Schiaparelli's paper on "Orbites cométaires, Courants cosmiques, Météorites," in Bulletin Astronomique, vol. 27, pp. 194–205 and 241–254, 1910. It embodies some points of view slightly different from those presented by me. The technical contributions by Fabry, Fayet and Strömgren are extensive and of a high order of merit; and students of comets cannot afford to neglect them.—W. W. C.

are closely related in one sense to some of our planets. About three dozen are in the so-called Jupiter-family of comets. The orbits of all those discovered up to 1893 are represented in Fig. 2. It is seen that the outer parts of all of them—the aphelia—are in the vicinity of Jupiter's orbit. Similarly, there are a few comets related to Saturn's orbit, a few to the orbit of Uranus, and six comets to the orbit of Neptune, one of the latter being Halley's comet. The Jupiter comets have periods lying between three and nine years, and the Neptune comets complete their circuits in from sixty to eighty-one years.

What has been the history of these short-period comets? H. A. Newton and other investigators have shown that it would be impossible for great numbers of comets, such as have been observed, to move through the solar system, without a certain proportion having their orbits changed into short-period elliptic orbits. It is the accepted view that the short-period comets have been captured, so to speak, by the combined attractions of the sun and one of the planets in each case. The chances of capture by the planets are greatest when the approaching bodies are moving in orbits which lie in planes most nearly coincident with the plane of the planetary system, and when their motions around the sun are from west to east. Newton's analysis of the problem led to the conclusion that five or six times as many captured comets should move in the direct sense, west to east, as in the retrograde sense, east to west. Now the only comets with periods less than 100 years which are revolving around the sun in the retrograde direction are Halley's comet, period seventy-six years, and comet 1866I, period thirty-three years. The three dozen members of the Jupiter family revolve from west to east without exception. That the motion in the short-period orbits is so universally from west to east finds the most probable explanation in the view that the cometary materials, when they were farthest from the sun, long before they approached the region of the planets and the sun, already had a slow motion from west to east, the motion of the parent mass of matter from which the solar system itself was developed. The French astronomer, Faye, on the assumption that comets have originated in the outer parts of a rotating mass which has developed into the solar system, came to the conclusion that comets should move prevailingly in the direct sense when their orbit planes do not differ greatly from the orbit planes of the planets, but that those whose orbit planes make great angles with the plane of the solar system should show no preference for the direct over the retrograde motions. These theoretical results are in good accord with the observed facts.

Our second question is, what are comets?

Comets have certain characteristic features:

1. There is always a head, or coma as it is sometimes called, a shin-

FIG. 3. HALLEY'S COMET, MAY 1, 1910; head and beginning of tail.

ing mass of hazy, nebulous matter. The head is sometimes circular in outline, more frequently elliptical or nearly so, but again it is oval on the edge facing the sun and it merges insensibly into the tail on the side opposite the sun (Figs. 3, 4 and 5). The sizes of comet heads vary enormously. One less than 10,000 miles in diameter would be most unusual and generally would escape discovery. The head of the great comet of 1811 was at one time more than a million miles in diameter. The head of the great comet of 1882, which many of us

dimensions. When a comet is observed at a great distance from the sun, only the head and nucleus are usually visible. The tail develops with close approach to the sun. The tail of the comet of 1882 was at one time more than 100 million miles in length; that of 1843 was at one time 200 million miles. As comets recede from the sun, the tails diminish in extent and usually disappear long before the head and nucleus are lost to sight. Several of the Jupiter comets do not have

FIG. 5. HOLMES'S COMET OF 1892; no tail was visible in the telescope; long-exposure photographs (Barnard, 3 hours, 1892 Nov. 10) recorded an extremely faint tail extending down to lower right corner of the picture. The great spiral nebula in Andromeda was recorded on the photograph—upper left corner of picture.

visible tails (Fig. 5). They appear not to possess in abundance the materials which go to form comets' tails.

4. When comets approach relatively close to the sun the heads frequently throw off a series of concentric shells or envelopes. The materials composing these envelopes appear to be expelled from the head and toward the sun at high speed, but these speeds of approach to the sun seem to be gradually overcome and the materials turned away from the sun to assist in forming the tails (Fig. 4).

The tails of comets, it is well known, point away from the sun. However, the popular view that they point *exactly* away from the sun is seriously in error. In general they lag behind the line passing through the sun and the comet's head (Fig. 6). There can be no doubt that they point away from the sun because of some repulsive force, originating in the sun, which acts upon the minute dust particles or gas molecules released from the comet's head. It takes time for these particles to travel out millions of miles from the head, and,

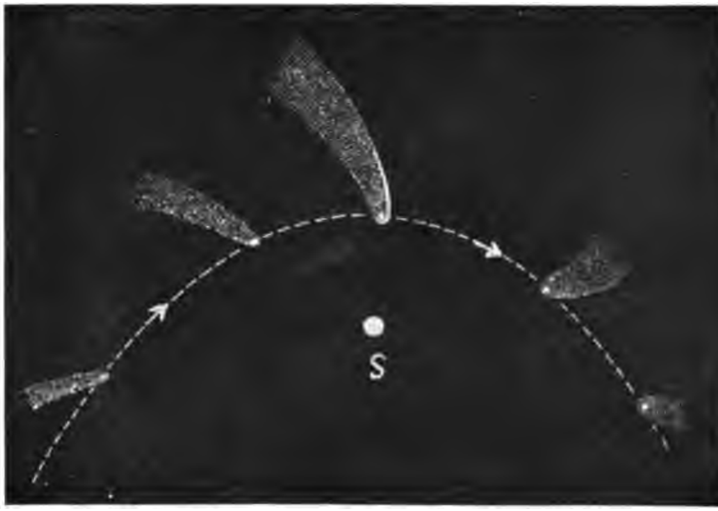


FIG. 6. COMETS' TAILS LAG BEHIND THE LINE JOINING THE SUN (S) AND THE COMETS' NUCLEI. Orbital motion is carrying the nucleus of the comet to the right.

while they are moving out, the head is moving forward in its orbit. The nucleus obeys the gravitational attraction of the sun absolutely, so far as observation has gone, and we have no reason to suspect that it is subject to an appreciable repulsive force. The particles composing the outer regions of the head and the particles composing the tail are doubtless attracted by the gravitation of the sun and are at the same time driven away by the repulsion of the sun. What the particles will do under the action of the two opposing forces depends upon the ratio of these forces. If the repulsive force is vastly stronger than the attracting force the particles will travel out from the head with great and increasing speed and form a tail pointing nearly away from the sun; that is, it will lag behind very little. If the attracting and repelling forces acting upon another group of particles are not very unequal those particles will form a second tail having considerable lag. If the repulsive force is very weak with reference to the sun's attractive force upon a third group of particles, they will form a short tail that lags very far behind. The forms and

FIG. 7. DIAGRAM ILLUSTRATING THE THREE PRINCIPAL TYPES OF TAILS OF COMETS. Orbital motion is carrying the nucleus to the left. The Sun is below.

that there were three classes of tails, corresponding to three fairly definite ratios of repulsive to attractive forces, as indicated by three different degrees of lagging behind the line joining the sun and the head (Fig. 7).

Bredichin determined that the long slender tails, observed in a few comets, which lag behind only slightly are the result of a repulsive force twelve to fifteen times as intense as the attractive force. He found another class of comet tails, of medium lag, for which the repulsive forces were from 2.2 to 0.5 times the attractive forces. Another class of tails, short and bushy, with very strong lag, were explainable on the assumption that the repulsive forces were relatively weak, from 0.3 to 0.1 of the attractive forces.

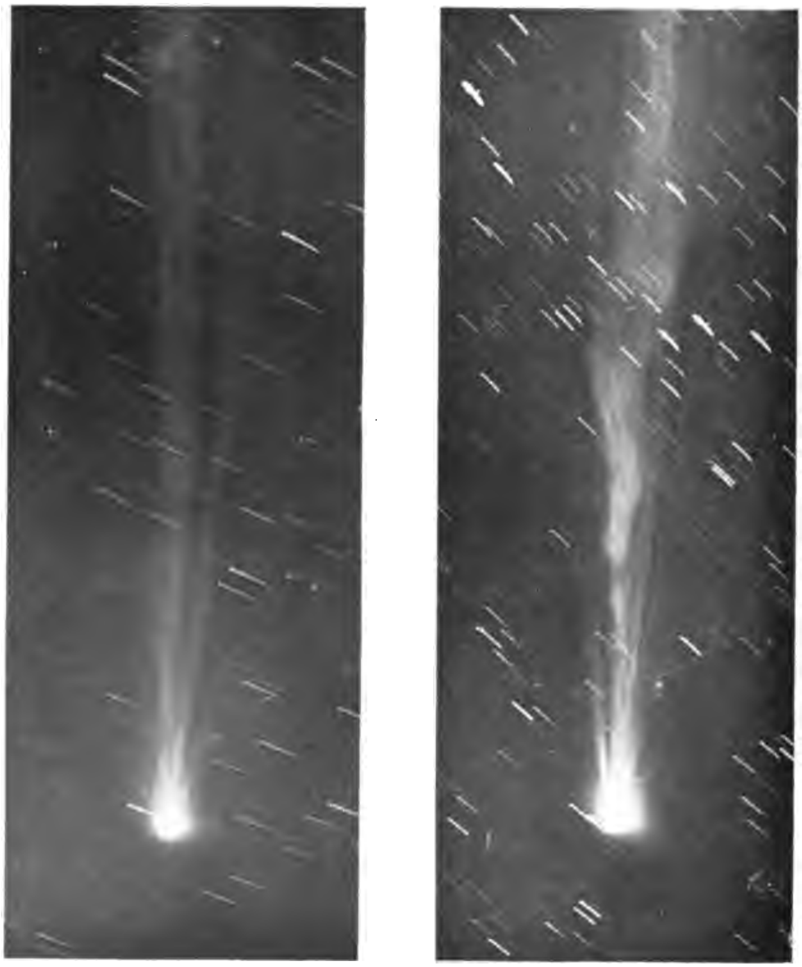


FIG. 8. COMET RORDAME ON JULY 12 AND JULY 13, 1893. The camera followed the nucleus of the comet and the stars "trailed."

In some comets only one of these three classes of tails is present, and again in one and the same comet all of the classes may be present at the same time.

That there is outward motion of the tail materials admits of no doubt. It is not uncommon for the tail materials of one night to be driven off into space, scattered and lost to sight, and for an entirely

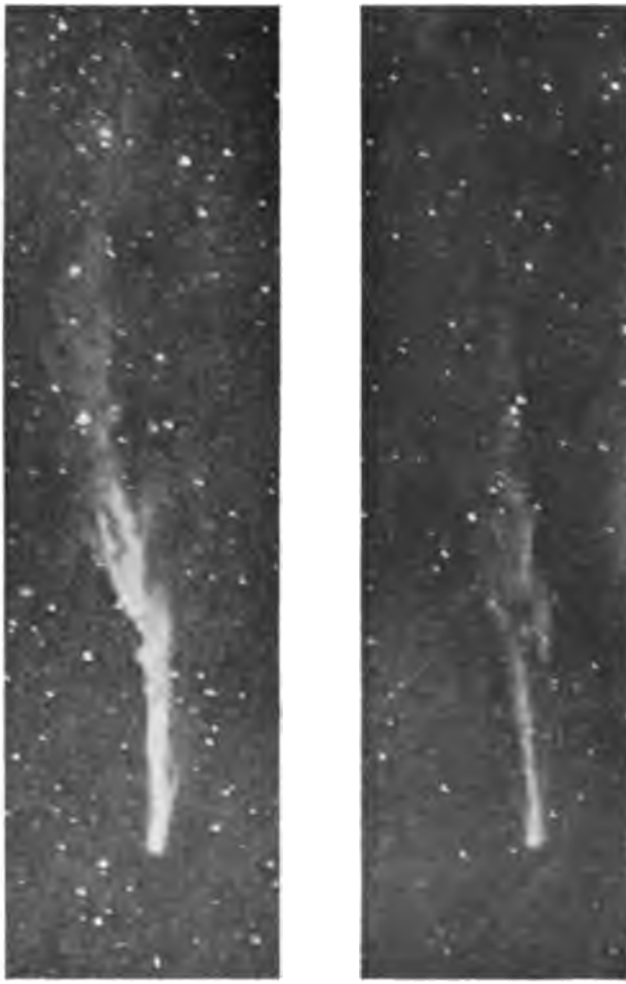


FIG. 9. COMET BROOKS ON OCTOBER 21 AND OCTOBER 22, 1893.

new tail to take its place by the following night. A comet's tail is constantly forming and moving out. The tails of comet Rordame (Fig. 8) photographed by Hussey on two successive nights, July 12 and 13, 1893, have no points of resemblance. The streamers composing the tail on one night are fairly straight, regular, and rather faint. The

well-defined nuclei, and it is brighter than the tail of the twelfth. Two photographs of this comet were fortunately made on the second night, with a time interval of three quarters of an hour. A comparison of the positions of the three nuclei on the two plates showed that they had moved outward from the head with great speed during the interval. The nucleus nearest the head had traveled out with a speed of forty-four miles per second, the next nucleus with a speed of fifty-two miles a second, and the one still farther out with a speed of fifty-nine miles per second. Here are two photographs of comet Brooks (Fig. 9) made on October 21 and October 22, 1893, by Barnard. The structure of the tail on the first photograph is not at all the structure on the second. The tail of the first night has been scattered to invisibility and an absolutely new tail has replaced it. The outward motion of well-defined tail structure has been measured for many comets. Here is a series of measures made by Curtis upon points in the tails of Halley's comet.

Average Velocities of Recession, from the head, of Matter in the Tail of Halley's Comet

Date, 1910	Mean Distance from Head	Average Velocity
May 23	800 miles	0.6 miles per sec.
May 27–28	400,000 miles	8 miles per sec.
May 25–26	930,000 miles	12 miles per sec.
June 2–3	1,360,000 miles	20 miles per sec.
May 28–29	1,730,000 miles	23 miles per sec.
June 6	2,200,000 miles	27 miles per sec.
May 26–27	2,500,000 miles	24 miles per sec.
May 30–31	6,600,000 miles	45 miles per sec.
June 7–8	8,400,000 miles	57 miles per sec.

The points to be measured were not well defined, and the measures could not be accurate, but it is clear that high speeds and accelerated speeds prevailed. The tail materials start out slowly from the head, and increase their speeds with the distance from the head, as we should expect of motion resulting from the action of a continuous force which meets with no sensible resistance.

In Fig. 10 are reproductions of photographs of Halley's Comet made by Curtis on June 6 and June 7, 1910. A semi-detached part of the tail, seen on the photograph of June 6 about an inch above the head, is visible about two and a half inches above the head on the photograph of June 7. This structure was first observed by Curtis shortly after it had emerged from the central part of the head on June 4, and it was recorded on the photographs secured by a great many observatories in the following four days, as the rotation of the earth carried the comet successively into position for observation at the observatories. The times when the lower point of the structure had certain positions is

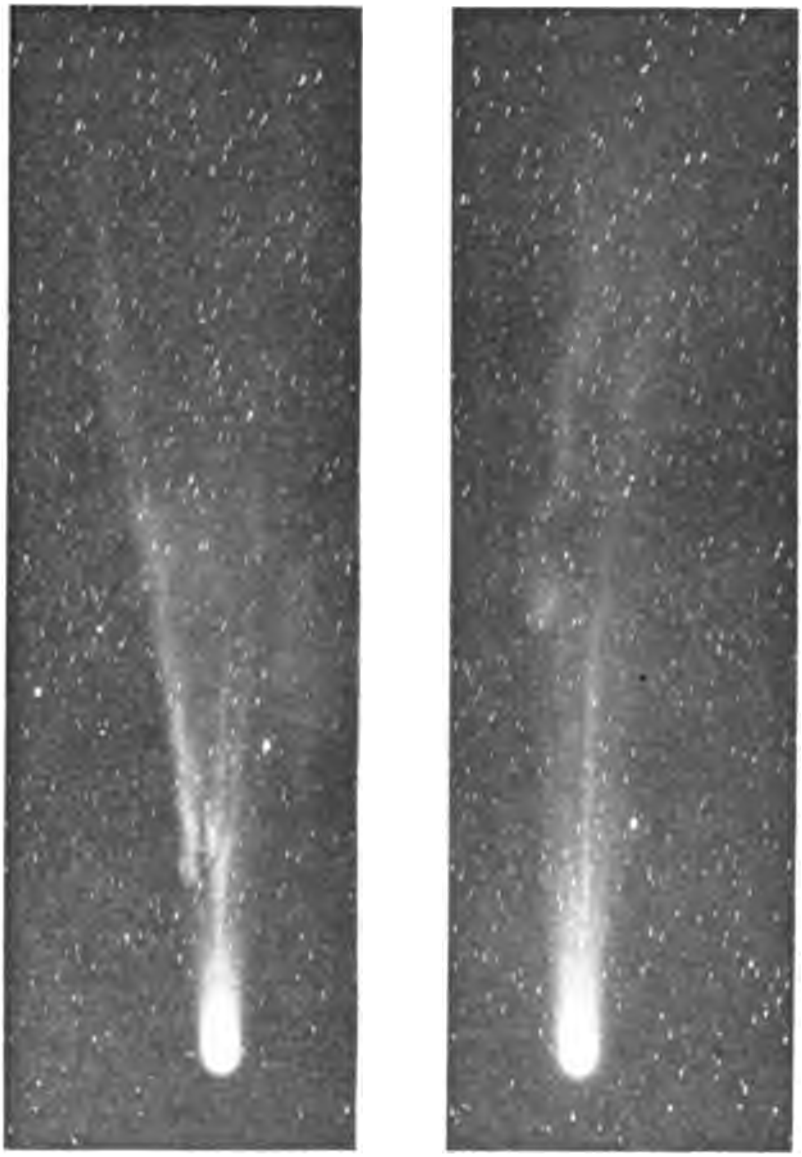


FIG. 10. HALLEY'S COMET, JUNE 6 AND JUNE 7, 1910.

indicated in Fig. 11. The tail did not seem to lag behind the position of the radius vector—the line passing through the sun and the comet's nucleus—because the observers on those days were nearly in the plane of the comet's orbit and the lag of the tail was toward the observers. The velocity with which the structure moved out in the tail was strongly accelerated with the passing of time, as may be seen from the chart.

require that comets in general grow fainter with time. This is the logical conclusion, and the observational evidence for it is undoubted in many of those comets which return again and again to the region of the sun. Nearly all of the Jupiter comets have a hazy, washed-out appearance. Several of them do not develop tails, as if their supply of tail materials had already been exhausted by expulsion as former tails. Others of them develop only very short tails, and several short-period comets have entirely disappeared. To this phase of the subject we shall return.

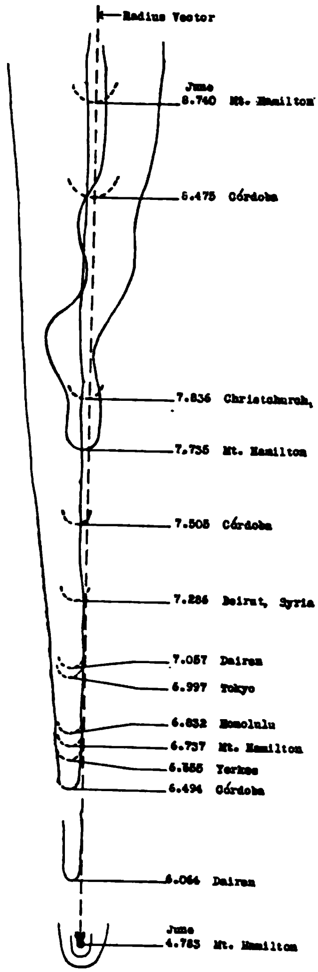


FIG. 11. SUCCESSIVE POSITIONS OF THE INNER END OF A DETACHED TAIL OF HALLEY'S COMET, JUNE 4–8, 1910.

As to the nature of the repulsive force responsible for comets' tails: It was long thought to be electrical, arising from a strong electrical field about the sun and from electric charges of the same sign on the particles composing the tail. The idea is in part purely speculative, but the giving of serious consideration to it is justified because of the fact that much of the light of comets seems to arise from electrical conditions in them. The idea may be wrong in toto, or an electric repulsive force may be one of two or more forces which are acting. It can hardly be the only force involved.

Clerk-Maxwell half a century ago, from pure theory, and Lebedew and Nichols and Hull some fifteen years ago, from experimental evidence admitting of no doubt, showed that when light energy falls upon a surface it presses against that surface; very feebly it is true, but it will cause the body pressed upon to move if that body is not too massive. In this respect light-pressure repulsion and electric repulsion should act much alike. These repulsions are effective in proportion to the surface areas of the bodies acted upon, whereas gravitation pulls those bodies with a force proportional to their masses. Now the surface of a body is proportional to the square of its dimensions, whereas gravity acts in proportion to the cube of its dimensions. The smaller a body is the more surface it has in proportion to

its mass. Electric and radiation-pressure repulsions will therefore act more efficiently upon very small particles than upon large ones. A cube of water one centimeter on each edge would be drawn by the sun's gravitational action 10,000 times as strongly as the pressure of the sun's rays falling upon that body would repel it. But a cube of water only 1/1000 of a mm. on each edge would be in equilibrium under the sun's gravitational attraction and the sun's light-pressure repulsion. A cube of water less than 1/1000 mm. would actually be driven rapidly away from the sun. The equilibrium diameter for little spheres of water, according to Nichols and Hull, is .0015 mm. Now as light energy is traveling along with a speed of 186,000 miles a second, we should expect particles of matter considerably smaller than the equilibrium size to travel away from the sun with great and rapidly increasing speeds. These speeds would be the greater for particles smaller and smaller until a certain limit of size with reference to wave-length of light is reached, after which the light would be diffracted without transmitting so large a proportion of its repulsive energy to the particles. These limits of efficiency were determined by the lamented Schwarzschild. The resistance of cometary particles is evidently also a function of the specific gravity of the particles. The figures which we have quoted are for water, density 1. We can scarcely doubt that radiation pressure is an important force, perhaps the chief force, perhaps the only force responsible for the driving out of the materials of comets' tails. Particles of solid matter or gas molecules of three different classes of sizes might be responsible for the three main classes of comets' tails. More probably materials of three different classes of density compose the three classes of tails. Bredichin called these three classes the hydrogen, the hydrocarbon and the iron tails. The atomic weights of these three substances give to their atoms or molecules about the right mobility, under equal pressure upon all, to explain the lags of the three classes of tails. Unfortunately it is far from certain that hydrogen exists in comets, and iron has been reported for only one comet.

The hoods or envelopes (Fig. 4) which form the outer strata of the heads of comets which come close to the sun are very interesting. It is the prevailing view that, when a comet approaches the sun, the solar heat falling upon that surface of the comet which faces the sun generates or liberates the gases and vapors which have been contained in or between the more solid parts of the comet; and being liberated, in effect, under pressure, the materials at first travel toward the sun with considerable speed. The sun's repulsive force acts upon these jets and, overcoming the forward motion of the materials, it eventually turns them back along the tail. Those phenomena have been observed many times.

variety of cometary contents or conditions. In some cases the spectrum seems almost wholly continuous, as in Holmes's comet of 1892; in others the light when passed through the spectroscope falls almost wholly into isolated bright lines or bands, as in Morehouse's comet of 1908. Other spectra are a combination of continuous and bright-line light (Fig. 12). The spectrum of the nucleus seems to be always continuous, or continuous except for absorption lines. In some of the brighter comets the nucleus spectrum as photographed contains the well-known absorption lines visible in the sun's spectrum. These observations indicate that the nucleus is shining, at least mainly, by reflected sunlight. In most comets the continuous spectrum is too faint to let us photograph it and thus to prove the presence or absence of the solar absorption lines. The continuous spectrum in many

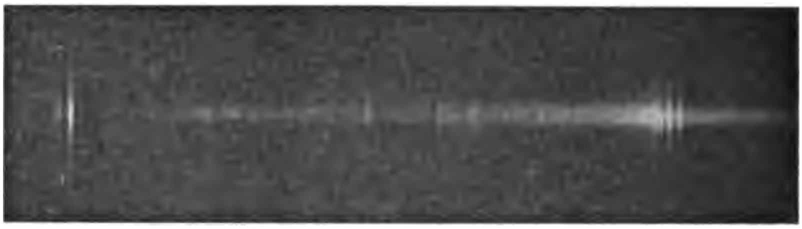


FIG. 12. SPECTRUM OF COMET DANIELS, 1907.

comets extends also to the head, or at least to the inner strata of the head. This may or may not mean reflected sunlight. It may mean some other form of luminescence which yields a continuous spectrum. The greater parts of the heads of comets and those parts of the tails of comets which are close to the heads nearly always, and perhaps in every case, give a characteristic spectrum of bright bands, which were for several decades called the hydrocarbon bands. Observations of recent years have made it probable that this spectrum does not indicate a combination of hydrogen and carbon, but that it is either one of the low-pressure carbon vapor bands or that it results from one of the compounds of carbon and oxygen, preferably from carbon monoxide. The lines and bands of cyanogen—a nitrogen compound—and of carbon are present without any question in the heads and inner tails of many comets. Several observers have reported that the so-called hydrocarbon spectrum of the heads and inner tails extends far out into the tails. This may have been true for the cases reported, but recent observations are casting doubt upon the presence of that spectrum in the outer extensions of comet tails. Improved methods of photographing comet spectra were applied to the bright comets, Daniels of 1907 and Morehouse of 1908, especially by Deslandres, Evershed and Chrétien,

with the result that their tail spectra were proved to be very different from the prevailing spectra of comets' heads and inner tails. Fowler has succeeded in duplicating the tail spectra of these two comets, in his laboratory, with remarkable agreement (Fig. 13), by photographing a cathode spectrum of carbon monoxide in a tube reduced to pressure not exceeding .01 mm. At higher pressures than this he obtained the so-called hydrocarbon spectrum, but it was not certain, and in fact it was improbable, that there was any hydrogen in the tube. The presence of carbon and nitrogen in comets is certain, the presence of oxygen is probable, and the presence of hydrogen is doubtful.

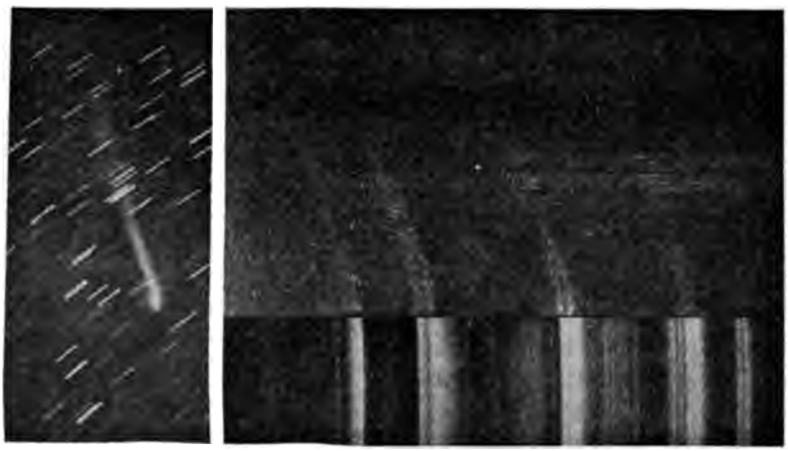


FIG. 13. (a) Ordinary photograph of Comet Morehouse. (b) Spectrum photograph of Comet Morehouse made at same time as (a). (c) Fowler's spectrum of carbon monoxide, whose principal bands match the principal spectrum images of the comet's tail.

The comets which have approached very close to the sun turned to a yellowish orange in color and remained so while in the vicinity of the sun, because the yellow light of sodium then developed strongly in them, apparently by virtue of the intense heating of the cometary matter by the sun's rays. This happened with the Wells comet of 1882, the great comet of September and October, 1882, the brilliant comet in January, 1910, and others. When the September, 1882, comet was only a few hundred thousand miles from the sun, Copeland and Lohse observed not only the sodium lines but half a dozen other bright lines which they concluded were well-known iron lines.

What is the origin of the light which gives bright lines and bands? The sodium lines certainly, and the iron lines if actually observed, were no doubt due to incandescent vapors of those elements under the intense heat of the sun. Strangely enough, when the sodium comets approached the sun, the carbon bands, which had previously been promi-

receded to a considerable distance from the sun and the sodium lines were no longer in evidence. The carbon light could scarcely be generated by heat action, for if so the carbon bands should have been in evidence during the time that the comet was passing nearest to the sun. Much more probably the bright-line spectra of the head and tail are of electrical origin, or fluorescent. This phase of the subject is technical, and to some extent speculative, and we can not profitably pursue it further on this occasion.

A certain proportion of the light of many comets is slightly polarized. The interpretation of this phenomenon is that a fraction of the light of the heads and of the inner tails of comets is sunlight diffracted by minute dust particles or gas molecules in the comet structure.

Returning to the subject of the disintegration and disappearance of comets:

A small comet was discovered by Montaigne in 1772. A comet was discovered by Pons in 1805. A comet was discovered by Biela in 1826. Biela computed the orbit of his comet and found it to be moving in an ellipse of period six and a half years, and he proved that the three comets discovered respectively by Montaigne, Pons and himself were identically the same comet. Biela's comet was rediscovered in 1832, almost precisely in its expected place. The next return was missed because the body was not in good position for observing. It was rediscovered in 1845, when it was seen to consist of two comets moving side by side on orbits almost identical. In 1852 both comets were reobserved, but farther separated than they had been in 1845. The comet was searched for at the proper times for several later returns, but it was never seen again.[5]

Kirkwood published in 1872 a list of eight comets which had divided in a similar manner and disappeared.

A number of other comets have completely disappeared, though their orbits were very well determined.

This brings us to another interesting phase of our subject:

The Perseid meteors are with us at this time of the year. Many of them have been seen every year for several decades. They are usually most numerous on the nights of August 9, 10 and 11. Predictions concerning meteors are somewhat risky, but so faithfully have the Perseids come every August that I have no doubt an observer to-night, to-morrow night and the next night, from midnight on to daylight, would see dozens of meteors whose paths traced backwards would pass through a small area in the constellation of Perseus. In 1866 Schiaparelli computed the orbit of the Perseid meteors and noticed that it

[5] One of the components of the Biela comet may have been observed for a few hours from Madras in 1872.

was essentially identical with the orbit of Comet 1862III. Here are the elements of the two orbits.

Orbits of	Meteors of August 9, 10, 11	Comet 1862III
Perihelion passage	July 23.62	August 22.9
Longitude of perihelion	343° 38′	344° 41′
Ascending node	138 16	137 27
Inclination	63 3	66 25
Perihelion distance	0.9643	0.9626
Period of revolution	105 years?	123.4
Direction of motion	retrograde	retrograde

The difference in the two perihelion times does not mean that their orbits were different even to the minutest degree, but only that, moving on the *same* orbit, they reached the point nearest the sun at slightly different times; that is, one of the bodies traveled over the orbit a little in advance of the other. The revolution period assigned to the meteors is subject to considerable error because it is not possible to observe the paths of the meteors with great accuracy.

There were rich and startling showers of meteors on November 12, 1799, and on November 12–13, 1833. H. A. Newton examined the literature of meteoric falls and found that many similar showers had been observed at intervals of thirty-three years running back several centuries, to 902 A.D., "the year of the stars," and he confidently predicted that another great shower would occur on November 13–14, 1866. His prediction was abundantly verified. Early in 1867 Schiaparelli and Le Verrier independently computed the orbit of these meteors, and Schiaparelli and Oppolzer independently found it identical with the orbit of the comet 1866I. Here are the elements of the two orbits:

Orbits of	Meteors of November 13	Comet 1866I
Perihelion passage	November 10.092	January 11.160
Longitude of perihelion	56° 25′.9	60° 28′.0
Ascending node	231 28 .2	231 26 .1
Inclination	17 44 .5	17 18 .1
Perihelion distance	0.9873	0.9765
Eccentricity	0.9046	0.9054
Semi-major axis	10.340	10.324
Period of revolution	33.250 years	33.176 years
Direction of motion	retrograde	retrograde

It is impossible to doubt that these November meteors and the comet referred to were traveling in the same orbit.

The so-called Lyra meteors are visible about April 20 each year. It was noticed in 1867 by Weiss that the orbit of the Lyra meteors is essentially identical with that of the comet 1861I.

as a double comet, was expected to return in 1866 and again in 1872, but it was not seen then, nor later. A meteor shower of moderate intensity was observed on November 27, 1872, moving in the orbit of the lost comet.

Not to dwell upon the remarkable identities of the orbits of the four meteor swarms, respectively, with the orbits of the four comets (Fig. 14), two of which have disappeared, and the other two, of relatively long periods, which may never return, we express the prevailing opinion of astronomers in saying that the meteor streams have actually resulted from the disintegration of the four comets. Alexander Herschel has prepared a list of seventy-six meteor streams whose orbits agree fairly closely with seventy-six comet orbits. A certain proportion of the suspected identities probably represent facts. It is inter-

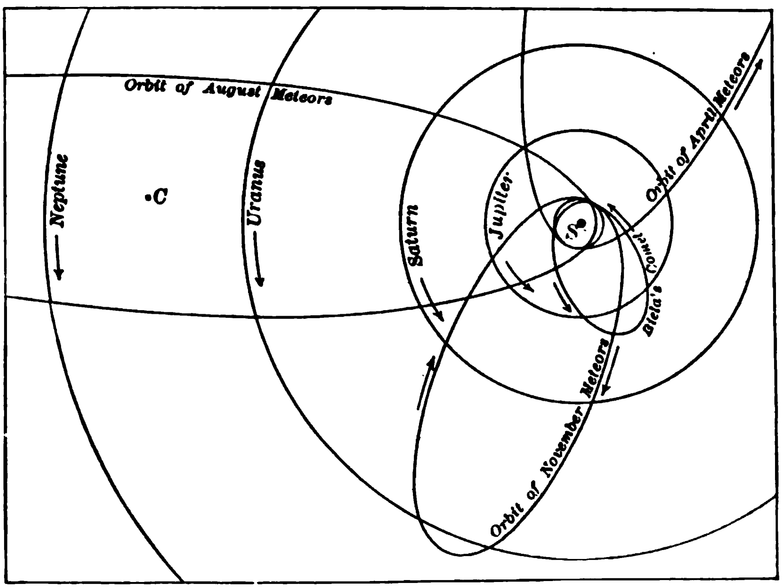


FIG. 14. ORBITS OF METEORIC SWARMS, which are known to be associated with comets.

esting to note that even as early as 1861 the truth of the situation was expressed and printed by Kirkwood:

> May not our periodic meteors be the debris of ancient but now disintegrated comets whose material has become distributed around their orbits?

It was in this connection and at that time that Kirkwood was able to make a list of eight comets, each of which had divided into two or more parts and had wholly disappeared from the sight of observers.

The cause of the disintegration of comets is not far to seek. A

comet's nucleus is thought to be a collection or cluster of small bodies, such as have been observed to collide with our atmosphere and to produce the meteor showers. They are held together, so to speak, while they are far away from the sun, because of their own very small but sufficient attraction for each other; but when they come within our planetary system, and especially when they come relatively close to the great planets Jupiter and Saturn, the sun and the planets attract the nearer particles of the comets more strongly than they do the farther particles. The nearer particles forge ahead on smaller orbits, the farther particles lag behind on larger orbits, and in the course of centuries the cometary material is strewn along a great stretch of the orbit. Other separative forces—of magnetic or electric natures, for example—may develop amongst the particles composing the nucleus as a comet approaches the sun. The intensity of the reflected light in all parts of the scattered comet structure becomes too small to let us see the remains of the comet, except as the remnants collide with the earth's atmosphere. There is certainly no reason to doubt that a very great many of our shooting stars are the remains of disintegrated comets. Tens of millions of little meteors enter our atmosphere every twenty-four hours and with rare exceptions are consumed by the heat of friction with the atmosphere when they rush through it at tremendous speeds. The gases from the combustion enter the atmosphere, and the ash and other unconsumed parts fall down to the earth's surface in due time. Accumulated meteoric dust is found in the perpetual snows at the tops of high mountains, and Sir John Murray found it in the ooze brought up from the depths of the oceans. Whether the meteorites which penetrate our atmosphere and are found and placed in our museums are parts of ancient comets can not safely be asserted, but it seems entirely possible that some of them are. However, it is not certain that any meteorite found on the earth has come from a meteor stream of recognized cometary origin. It is pretty well established that many of the sporadic meteors which plunge into our atmosphere were traveling on hyperbolic orbits.

We discover only a certain proportion of the comets which come close to the sun and to the earth. The numbers which course through the planetary system and remain undiscovered by the observers on the earth must be exceedingly great. The supply of cometary material in the remote outskirts of the planetary system must be enormous. This material is probably in the nature of remnants of the nebula or other mass of matter from which the sun, its planets and their moons developed. This idea is to a certain extent speculative; but that the cometary material is now out there in abundance we can not doubt. Much of it naturally consists of matter in the solid state; and, the sun's attraction at that great distance being almost zero, neighboring masses

could slowly come together as a collection of small solid masses, such as seem to compose the nucleus of a comet. Such a nucleus could attract and attach to itself any dust particles and molecules coming within its sphere of attraction. These might well, and probably would, include a collection of finely divided matter that had already been driven off in the tails of comets which in earlier ages had visited the sun. The materials thus collected would be attracted by the sun, a few of the collections would eventually pass comparatively close to the sun, a few of the latter would be discovered as comets, and a part of the finely divided material contained in them would be driven off again as comets' tails into space, possibly to return many times in the bodies of comets coming later into the sun's neighborhood. Certain of these bodies would come so close to the planets as to have their orbits transformed from very long ellipses to very short ellipses. These comets would be disintegrated and their materials be widely scattered. We have seen that the earth has collided with such materials, and the earth is growing slowly, very slowly, through the deposition of the remains upon its surface. Probably a little of the same materials goes likewise to other planets of the solar system and adds slowly to their masses. However, an insignificant proportion of the materials scattered in this manner through the solar system is thus accounted for, and the remainder doubtless revolves around the sun in ellipses, probably contributing its share of reflected sunlight to the faint glow near the sun known as the zodiacal light.

We have seen that devoted students of comets have learned much concerning these interesting travelers. Many mysteries have been removed, but many questions remain for the astronomers of the future to answer. We should especially like to know more of the physical conditions existing in comets, more about their chemical contents, and more as to why and how they shine by their own light. Perhaps the most valuable result of cometary investigation has been the emancipation of civilized peoples from unreasoning and groundless fears of these bodies, which come and go in obedience to the same simple laws that govern our every-day affairs.

THE STRATEGICS OF SCIENTIFIC INVESTIGATION

By Professor T. BRAILSFORD ROBERTSON

UNIVERSITY OF CALIFORNIA

The thirty spokes unite in one nave; but it is upon the space for the axle that the use of the wheel depends.—Lâo-Tsze.

IN all ages and among all races since man first made his début upon our earthly stage, certain individuals have differed from their fellows in the possession in unusual measure of impersonal curiosity combined with powers of observation, comparison and generalization. Where historic record fails we can infer the existence of these individuals from the heritage of knowledge which they conferred upon their descendants. Such knowledge did not come to man by revelation, or rather, let us say, the revelations of past ages did not differ in kind from those of our own time. The mental exertions which led to the development of the stone axe from the fortuitously encountered sharp fragment of flint did not differ in kind, possibly not even in degree, from those which led to the development of the aeroplane from a Chinese toy.

These individuals, whom I prefer to call investigators, avoiding alike the barbarism of the word "researcher" and the restricted connotations of the word "scientist," have but rarely, at any stage of the world's history, appeared of any importance in the eyes of the acknowledged rulers and leaders of mankind. In so far as they have occasionally combined charlatanry with science, as in the case of the ancient or medieval astrologers or a certain type of modern inventor, they have, it is true, occasionally achieved notoriety and the consequence attaching to the recipients of the beneficent toleration of rulers. In times of actual and impending disaster the desperate ruler not infrequently turned to his men of contemplation, to his astrologer, his magi or to Archimedes, with the helpless confidence with which the stricken patient turns to the surgeon upon whose labors he has never bestowed a thought in his days of health. History repeats itself, because the politicians and financiers of to-day are merely protean forms of the satraps and merchants of Persia, or the senators and bankers of old Rome placed in a different material setting, and the parallel between the European governments of to-day turning desperately to science for aid in the extremity of their peril and the Oriental emperor who in a like pass appealed to his wise men who were versed in the stars, would be comic indeed, were it not so unutterably tragic.

It has been but rarely, and then wholly fortuitously, that the investigator has been valued as a potent factor in society. In those rare instances it has been the individual who was valued, not the type, and the value has generally been that which the collector places upon a unique item in his collection, or which the vaudeville artist places upon his performing panther, or that vague and fruitless veneration with which the sage, the hermit or the dear old unpractical sweetly-disposed rector of an English village is not unfrequently regarded—veneration which arouses no desire of emulation, but which finds its source in the incomprehensibility of the inspiring motive or its remoteness from the commonplace.

It has not infrequently been recognized by rulers that the patronage of learning has occasionally been rewarded by unexpected benefits, and from Hiero relying upon Archimedes for the defence of Syracuse to Christina of Sweden summoning Descartes to read to her before breakfast, rulers have sporadically contributed to the service of investigation. In modern times likewise it is officially recognized that the investigator may be an ornament to the state, but, save in the times of stress aforesaid, no hint of consciousness is betrayed that the labors of the investigator may constitute the very framework of civilization.

"Old women for old women," says Walpole, referring to the Royal Society, "I would trust to the analysis of the matrons in preference to that of the philosophers."[1] When the master-investigator of all time, Michael Faraday, ventured, in response to the ill-advised persuasion of his friends, to apply to government for a minute fraction of the recognition to which his incalculable services had entitled him, he was received by Lord Melbourne with the epithet "humbug." In 1914 when one of the greatest medical investigators of our day preferred a similar request to government his plea was received by the official overlords with the silent contempt of utter indifference.[2]

The mental attitude of the general public towards the investigator is similar to, but less financially profitable than, the attitude of tolerant and half-contemptuous admiration which is displayed towards the artist and the virtuoso, and it would be alike endurable were it not fraught with the very gravest dangers. What confidence would we possess in the lawyer unaware of the sources of common law or in the doctor who was professedly ignorant of the anatomy and physiology of the human body? What confidence shall we then display in the statesmen who remain oblivious and blind to the nature of the formative forces which under their very eyes are continually refashioning civilization? A momentary recognition of the danger of ignoring the investigator is,

[1] "An Account of the Giants Lately Discovered," 1766; Works of Horatio Walpole, 1798, Vol. 2.

[2] Cf. correspondence in the *Morning Post* and other London newspapers in the spring of 1914.

it is true, being displayed throughout the civilized world at present, owing to the crucial part which his labors play in the organized destruction of life and property which is the chief preoccupation of civilized peoples at this date. Good resolutions are being actively formed in Great Britain, America, Canada and Australia, resolutions which find expression in governmental plans for the future administration of scientific research. The education and training of the professional politician is, however, so purely legal, commercial and, in rare instances, literary, that it is not a matter for surprise that the various schemes for the furtherance of research which have thus amiably been put forward betray little comprehension of the real needs and potentialities of the investigator and little or no grasp of his true significance in world politics. Indeed the various plans which have been proposed will, if they materialize, carry with them very real dangers to true research and were the investigator as stridently vocal as the politician, I think it not unlikely that in many quarters at the present juncture earnest appeals might be heard from the scientific investigator to be saved from his friends and to be favored once more with the obscurity to which, like certain fish which dwell in caves, he has become by habitude adapted.

The various plans to which I have made allusion all bear indeed the unmistakable stamp of the mental bias of the political administrator. They unite in assuming that any given problem can be solved provided only the requisite number of persons, duly provided with diplomas, be paid to investigate it under the supervision of course of the omniscient administrator, who, in some of the plans I have instanced, is not even required himself to take part in the labors of his employees. Such tactics are well known to succeed in the production of public buildings, and while it may well be doubted whether they ever produced a Milan Cathedral, still they have given rise to many imposing edifices and why not, therefore, to the halls and corridors of science?

And then, of course, all of these plans unite in assuming that the public investment in science must be made to "pay." Now the author is far from taking the view of certain of his scientific colleagues that any association of commercial value with the products of research is inevitably accompanied by a degradation of ideals. The ultimate object of investigation lies in the attainment of complete control and understanding of our environment and only in so far as our environment is subject to control does it become of value to us. The whole difference between the value of our world to-day and that of the world inhabited by neolithic man is, as I have sought to show in a previous article, the product of the labors of the investigator. But these labors, however inchoate and devoid of the inspiration of a broad predetermined policy, have nevertheless in the past been for the greater part the result of an enlightened and penetrating curiosity and have not as

a rule been dictated by a sense of immediate or personal advantage. They have therefore resulted in the attacking of broad problems, for the nonce unprofitable but in their fruition how deeply fraught with significance to humanity! If the kind intentions of our political friends are executed, however, all this will now be changed, the old academic notion of the remoteness of the investigator from the every-day exigencies of life will be swept away, the unpractical investigation of the laws of atomic affinity will be replaced by an intensive study of cheese-making and the inspiring contemplation of the mysterious structure of the crystal will be replaced by a study of improved methods of hardening steel.

I am far from attempting to impugn the value or the ultimate as well as proximate importance of these studies of immediate practical concern. The Infinite lies hidden in every grain of sand and no object whatever is devoid of dignity as an object of research. Pasteur was led to his epoch-making investigations which have ameliorated so much of human pain and suffering by a study of the problems encountered in the manufacture of wine and of silk. Faraday's genius for research found the path to a new world through his attempts to provide manufacturers of optical instruments with a new and more satisfactory type of glass. But the doubt which assails me is this: Supposing our political friends had by happy chance engaged a potential Faraday or Pasteur to investigate the chemistry of cheese or the hardening of steel and suppose in the course of these utilitarian investigations he too were to tap a vein of knowledge leading deep into the heart of the mysteries of our environment, would he be permitted so unprofitable a divergence from the main object for which he had been hired? However sympathetically inclined his immediate overseer might feel, I think that it might be difficult to convey to the politicians to whom he in turn would be answerable the ultimate significance of such abstract and generalized investigations, and when in turn the matter came to be referred to voters, *i. e.*, taxpayers, I fear it would go hard with our new Faraday or Pasteur.

The wind bloweth where it listeth and the spirit of man can not be confined within premeditated bounds. This human institution, the institution of investigation, must like other human institutions be of natural and spontaneous growth or it will inevitably decay. Just as a church can not be established by statute, nor a system of law be perfected in the brief deliberations of a committee, so scientific investigation must develop of itself, by the expression of its own internal vigor, into an autonomous and self-supporting institution, integrally welded into our daily lives and the living expression of a need and a function of society.

Such, indeed, in slow and painful stages has been the past devel-

opment of science and such, in an accelerated measure, must be its development in the future. There is, indeed, a legitimate sphere for governmental enterprise in that gap between pure science and practical industry which has hitherto been so imperfectly bridged. But the activity of governments in this field can not stimulate the broader activities of the investigator and there is, on the contrary, ground for serious apprehension that the activities of governments in this direction may actually result in depriving the broader and ultimately more significant investigations of the means for their prosecution. The government institutes for research having been founded and munificently endowed, why should further grants and endowments be furnished for investigations which are not carried out under government control? The danger is that cheese-making and steel-making and the like being adequately provided with expert scientific advice the politician may decide that all is now well with the investigator and turn with relief to the more familiar problems of "practical politics."

In order to combat this tendency and to stimulate the spontaneous development of investigation in a measure commensurate with the accelerated velocity of modern social evolution, it is a vital necessity that investigators the world over should at this time take thought and counsel among themselves as to the new ways and means to be adopted, the secular changes in our procedure which will bring our institution of investigation more closely into harmony with the increasing complexity of modern development. Just as, from time to time in the world's history, when some crisis has brought into prominence the misfit between existing institutions and actual needs, the churches have changed and adapted their organization and the existing body of laws and legal procedure have been subjected to reform, so in this day of crisis our institution of investigation must be subject to a like scrutiny and the origin of misfit between existing need and existing procedure sought and if possible removed.

In past centuries the investigator has been largely content to rely for the satisfaction of his personal needs and those of his profession upon the largesse of patrons. So far this procedure has yielded results the vast import of which it would be impossible to exaggerate, and is unquestionably destined still, perhaps for many generations, to provide the main support of this service of mankind, but as the exclusive means of subsidizing investigation it is outworn and ill-adapted to the needs of our present time. To-day we see that increasing patronage, so far from constituting fresh opportunities for science, actually constitutes a grave danger to the welfare of the broader and more fundamentally important types of investigation. The channels are to be made deep for the ultimate trickles, but the fountain-head from which the waters of knowledge proceed is to be neglected, possibly in even greater meas-

ure than in the past, and we may well apprehend that in course of time it may become clogged to the serious impairment of its outflow. The remedy lies in our hands and individually or collectively the decision must be taken now. There is only one solution of our problem and that is to cast off our swaddling bands, cut ourselves loose from patronage, and take into our own hands the destinies of our own institution. While enlightened private patronage will still in a measure contribute towards the achievements of investigation in the future, in ever-increasing degree we must cease to be dependent upon others and look to the product of our own efforts to afford us the material foundation of fresh enterprises. I have elsewhere endeavored[3] to form some imperfect estimate of the monetary equivalent of the colossal value to which the accumulated investigations of mankind have given rise. Where values are so enormous, comprising almost the entire value of existence, such estimates are necessarily only fragmentarily valid. One fact is abundantly demonstrated, however, and that is that by far the greater part of the summated value of the manufacturing industries of our day owes its existence to and depends for its continuance upon the labors of the scientific investigator. Of the vast annual income which is realized by these manufactures and which arises out of their patents a barely discernible fraction ever finds its way back to furnish the means of providing fresh discoveries and fertilizing the field upon which we must rely for the production of fresh growths of industrial enterprise.

If the scientific investigators produce this vast wealth they can also in some measure control its disposal and by observing the guiding principle that in a steadily increasing degree investigation must be made self-supporting, they will undoubtedly in time be enabled to deflect some proportion of this wealth, and a very small proportion indeed would be sufficient, to the services of their institution.

In isolated and strikingly successful instances this principle has already been practically applied. The Solvay Institute in Brussels owes its existence to the wealth proceeding from the discoveries of Solvay. The Institute of Experimental Therapy in Frankfort to which medicine already owes practical results of stupendous significance is supported by the proceeds accruing from Ehrlich's patents and the Research Corporation in New York, deriving its income from the Cottrell patents, is the first instance of a more fundamental and far-reaching endeavor to place the institution of investigation upon a self-supporting basis. It is through repeated independent applications of this principle that the extensions and proliferations of research in future generations are to derive their material bases.

The objection will unquestionably be urged by many scientific pur-

[3] "The Cash Value of Scientific Research," THE SCIENTIFIC MONTHLY, 1 (1915), p. 140.

ists that this procedure would involve the "taint" of commercialism, that once the investigator enters into the market-place his ideals will be contaminated and the purity of his aims sullied. My reply to this is that a fundamental instinct of mankind can not be suppressed so easily. Investigation will proceed even if individual investigators fall by the wayside, and the distinguished instances of successful enterprise of this type to which I have drawn attention are living proofs that the investigators to whom they owe their origin were not so lacking in determination and enthusiasm as to relinquish their life-work merely because personal advantage tempted or the chaffering of the market disturbed them.

Churchmen in all ages have been known to sacrifice personal advantage to impersonal ideals, statesmen have occasionally placed patriotism before profit. Are investigators then so inferior to other men, of so delicate a moral and mental fiber that they will be ready to sacrifice their ideals at the altar of Mammon directly the opportunity presents itself? Or is it, that never having submitted to the trial they are needlessly distrustful of their own moral stamina? I doubt not that the objector would, if questioned, be confident of his own ability to hold fast his ideals, it would be the weaker brother for whom he would be solicitous. Well, let the weaker brethren go, for we can readily spare them, and they too may have their utility in the "debatable land" between science and industry to which I have alluded as a future sphere of governmental or commercial enterprise.

Should the few but noteworthy precedents which have already been set develop, as I am confident they will, into an avowed policy of the majority of scientific men, then a momentous thing will have happened, for science will have capital of its own to dispose of without fear or favor, without deference to the caprice of the patron or the objectives of a donor or the utilities of the moment. When this hour arrives the campaign of the conquest of nature will have entered upon a new phase, and, equipped at last to conquer, a definite strategy of investigation will have become an imperative necessity.

Investigation has hitherto proceeded haphazard, a compromise between the availability of funds and the talents and inclination of the investigator. These latter must always remain a determining factor, but the availability of the paltry means which are usually needful will, it is to be hoped, cease to determine with iron and senseless rigidity the evolution of civilization. At the present time it is comparatively easy to obtain money to endow astronomy, because the subject is in itself inspiring and has never lacked great popularizers and expositors and also perhaps in some measure because a telescope or an observatory is a visible monument to the donor. It is easy to obtain money for objects of real or fancied utility, for the investigation of certain aspects

of medicine or agriculture. But it is difficult to obtain money for the investigation of recondite phenomena in physics or chemistry or for such subjects, for example, as the psychology of insects. Yet if perchance the strategist of investigation were to survey the whole field of scientific knowledge as one might survey a map he would inevitably find that all subjects of investigation are closely interwoven and mutually interdependent. Slowness of advance in one direction cripples advance in another, lack of knowledge in some at first sight unrelated field prohibits the fruition of research elsewhere.

Then, again, apparent value is not in the least identical with the real or ultimate value of investigation. To the man in the street it may appear that the study of fertilizers or of soils, of minerals or of dyes affords at the present time the fields of prime importance. Without in the least detracting from the proximate and ultimate value of such researches, the biochemist, looking a few decades farther ahead, can see in the study of the phenomena of fermentation, of enzyme action, the germ of a future discovery, the artificial photosynthesis of carbohydrates, which will accomplish nothing less than an industrial revolution and sweep aside at one stroke the economic problems of immemorial centuries. Yet with such a possibility lying dormant in the subject, where do we find an elaborately equipped institution for the scientific investigation of enzymes, where leading investigators in the field are congregated and all the resources of modern physics, chemistry and biochemistry backed by the necessary equipment are brought to bear upon this field, fraught with such vital significance to man? If there exists indeed such an institute then I am ignorant of its whereabouts and of the names of the members constituting its staff. The field is not one which has appealed to patrons, the word fermentation reveals to them only the manufacture of beer, which is not the most inspiring of our industries. But the strategist of investigation would place his finger upon this spot in the terrain of scientific conquest and order up reinforcements to support the thinly scattered and ill-equipped forces which at present represent the sum total of human endeavor to enter into possession of this new world which lies before us.

Another subject which will doubtless greatly interest the future Parliament of Science will be that of the geographical distribution of investigation. Here, too, our absolute dependence upon patronage has unfavorably influenced the development of our institution. At present an enormous proportion of organized investigation is being conducted in the vicinity of the large centers of population in Europe and North America. That is partly because of the natural tendency of investigators to congregate in the neighborhood of the patron who endows their labors, and partly owing to the fact that in the absence of any Parliament of Science or analogous deliberative body to discuss such

those localities where opportunities are most abundant, new opportunities have been created for them and thus, if this centripetal process is to continue unmodified by some centrifugal policy of distribution, the facilities for research will tend to become in ever-increasing degree confined to a comparatively small number of centers of population.

It is, of course, having regard only to the effects and achievements of investigation, totally immaterial where it may be conducted, but from other points of view the present centripetal tendency of investigation is a serious handicap to the accelerated development of this function of society which is imperatively demanded by the rapidly increasing complexity of our social and material environment. In the first place the congregation of investigators in a single center leads, through constant personal interchange of views, to a certain uniformity of thought which, not infrequently, becomes indistinguishable from prejudice. The scientist who has travelled can not fail to have observed that his colleagues in Berlin, for example, all share a certain number of views regarding the field in which they labor; his colleagues in London will have a somewhat different group of opinions in the foreground of their thoughts, while those in New York will esteem yet a third group of phenomena or hypotheses as of prime immediate importance. This is inevitable, because no investigator, no matter how virile and creative his intellect, can form an opinion from personal, unprejudiced experience on every phase of his chosen subject and he therefore in such matters provisionally absorbs any plausible opinion which lies nearest to hand. His acceptance of such opinions is provisional and subject to revision in the light of fact, it is true, but prior to or failing such revision it must play its proportionate part in determining his mode of investigation in other fields. Obviously a centrifugal distribution of investigation would reduce this tendency towards gelation of hypotheses to a minimum and produce among investigators as a whole that catholicity of outlook and variety of attack which is the condition of success in the interpretation of the myriad manifestations of the complexity of our environment.

But the present centripetal tendency is fraught with yet more serious consequences, for centralization of investigation implies centralization of the opportunities for investigation. At the present date in New York, London, Paris or Berlin the young man who has capability for original investigation has every opportunity of acquiring facilities for his work and for gaining inspiration from the example of investigations proceeding to a successful issue in his own vicinity and under his own observation. He sees in actual operation the methods of work adopted by masters of his subject, and example and opportunity alike combine to make the path easy to his chosen career. But what shall

we say of the opportunities of the young man in Siberia, China, Australasia, South America or Africa? We can not doubt, in some instances we have living proof, that the populations of these countries, granted equality of opportunity, would produce their proportionate quota of talented investigators. In certain localities in these countries every necessary institution exists for providing the essential preliminary training of the investigator, but, training in the fundamentals of his subject secured, where is he now to turn for the living example of the great investigator or for the opportunities of a laboratory partly or wholly devoted to research? The bare possibility of creating fresh fields of knowledge in his chosen territory will probably never even occur to him, since he has never seen or been stimulated to imagine investigation conducted on a broad and practical scale. Thus he turns his energies to other fields and perchance may dissipate on trifles talents which would have been of priceless value to civilization. As a means, then, of tapping new sources of talent for investigation, a centrifugal disposal of investigators and the opportunities for investigation has now become a paramount necessity.

But long ere we can accomplish a fraction of these desirable reforms and developments of our institution a new spirit must arise among investigators themselves. For centuries they have held themselves aloof from the world and centered their regard too exclusively upon their chosen special fields. Few indeed are the investigators of the present day who devote any proportion of their time to reflection upon the ultimate import of their profession, fewer still are conscious of a uniting purpose binding them to the investigators of all lands and times, of the historical continuity of their labors, or of the vital significance of their function in society. The communal spirit which arises from the awareness of common aims and the certitude of irreplaceable usefulness which is the driving force of any and every human institution is as yet, in our institution of investigation, but inadequately aroused. If we are to take our rightful place in the scheme of things and acquit ourselves as becomes our responsibility we can not too soon take these fundamental aspects of our profession seriously into consideration.

And above all let no investigator be ashamed of his profession and let none regard his labors cheaply, for the investigator is the pathfinder and the pioneer of new civilizations; he is more than that, he is the interpreter of the Infinite.

THE DESIRE FOR FOOD IN MAN

By MINNA C. DENTON
OHIO STATE UNIVERSITY

IN these days there is hardly a more commonly accepted principle of human conduct than the tendency to supplant inherited instincts by experience based upon organized knowledge; nor will the teachings of unorganized knowledge prove an acceptable substitute. Unaided mother-love has brought up most of the babies reared to adult stature since the dawn of creation, yet it must confess that modern methods in medicine have bettered its instructions. No longer is it possible for the singer, the engineer, the nurse, the teacher, to make headway professionally without scientific training; and now the cook, the policeman, the saleswoman and the charity worker are beginning to follow suit.

Moreover, in regard to inherited instincts, it has to be admitted that they are sometimes altogether lacking upon most important occasions, or even fundamentally wrong. It is well known that though many animals, thrown into the water for the first time, can save their lives by swimming, the inexperienced human is usually unable to do so. The instinct for scratching an irritated skin is almost ineradicable, yet ordinarily mischievous and often dangerous. The universal liking for so powerful a poison as alcohol, so easily developed by all races of men, has sometimes been cited to disprove any possible theory of organic evolution. Such instances as these may easily be multiplied.

How does this apply to that absolutely universal, most important, and least considered (from the scientific standpoint) of all human performances, the every-day business of eating?

It is perhaps a self-evident proposition, that the human body is, physiologically speaking, a machine, *i. e.*, a complicated system of more or less perfectly coordinated mechanisms, for which foods serve the double purpose of supplying structural material and also fuel which keeps the engines running. It is a deduction which few would care to deny, that any machine will run better and last longer if built of proper materials suitably repaired, and fed with the proper kind of fuel, in amounts suited to the kind of work it has to do. Yet the universal criterion used by the builder, repairer and stoker of this machine is the desire to eat, dignified by some such name as "the normal healthy appetite," "natural instinct for food." And meantime, the tendency of physicians to use "regulation of the diet" rather than medicine, as

a means of combating a long and diversified list of human ills, seems to be constantly and most disturbingly on the increase.

It is to be observed that there is no immunity from any of these ills for the multitude who (explicitly or tacitly) maintain that eating should be entirely an esthetic performance, guided solely by refined and restrained sense gratification and adapted to encourage social intercourse; a performance, then, which can have as little concern with calories and protein, as has the music-lover's enjoyment of a beautifully taken high G, with a consideration of the wave-lengths of the vibrations which produced it. This attitude toward scientific nutrition has, needless to say, as little efficacy in warding off the physical ills resulting from dietetic errors, as has the behavior of the traditional ostrich toward the danger by which it is confronted.

Let us undertake an analysis of the motives involved in the desire for food, as they commonly operate among the various classes of people of our own day and country.

1. Hunger. Beginning with the more fundamental physiological motives, we find that recent investigations[1] seem to demonstrate conclusively a fact which most of us will be inclined to concede at once, or at least after a little reflection, viz., that hunger and appetite are distinctly different motives. Hunger is to be defined as an unpleasant sensation, referred by most people to the pit of the stomach or closely adjacent regions, not caused by the sight or thought of food, but by a certain type of contractions of the stomach muscles which begin as soon as the stomach has been emptied, in normal individuals, and which continue until food is taken. The degree of hunger sensation or pang to which (presumably) these muscular contractions give rise, varies in different individuals, and also, of course, in the same individual at different times. Both the muscular performance and the sensation occur intermittently at first, or in periods of varying intensity, but at length these periods become continuous if no food is taken. In prolonged starvation or undernutrition, however, it seems that the hunger *sensation* (though not the contractions) gradually becomes weakened. Hunger pangs and contractions are almost instantly stopped by the entrance of food or palatable substances into the stomach, or even by fused taste and smell sensations unaccompanied by the swallowing of food. A few spoonfuls of hot soup, though they may contribute little or no nourishment to the body, go far toward alleviating hunger pangs for the moment; even a drink of water sometimes helps; and this would be true even though the liquid were not swallowed, as was proved in case of Mr. V———, Professor Carlson's

1 Cannon and Washburne, "An Explanation of Hunger," *American Journal of Physiology*, Vol. XXIX., p. 441. Carlson, "Contributions to Physiology of the Stomach," *American Journal of Physiology*, Vols. XXXI.–XXXIX. incl., also "Control of Hunger in Health and Disease," University of Chicago Press.

man with occluded esophagus, who had to be fed with stomach tube. Such facts perhaps indicate to us the biological necessity for the co-operation of appetite with hunger.

2. Appetite is sometimes regarded as a fundamental inherited reaction, and sometimes as being wholly the product of educatlon, *i. e.*, of the individual's experiences with foods. In contradistinction to hunger, appetite is a pleasant sensation, and is invariably associated with the taste, smell, sight or memory of palatable food. It is dependent upon, or coincident with, changes not in the muscular walls, but in the lining membrane of the mouth and stomach. The familiar "watering of the mouth" or psychic secretion of the saliva, connected with the appearance and eating of food which is enjoyed, is a good illustration of these appetite phenomena; and exactly the same thing is happening at the same moment in the stomach, though the individual is not, of course, subjectively aware of this fact.

Here, then, are two great motives having altogether different physiological basis and action (*i. e.*, concerned with different tissues of the body), which ordinarily act together in bringing about and maintaining the desire to eat, until the amount of food taken shall have become adequate for sustenance.

The hunger motive, it seems, is extraordinarily independent of environmental and educative influences, except for certain habitual inhibitions. It can by certain means be caused to disappear instantly, but can not readily and immediately be caused to appear or increase. The strength of its contractions and pangs is, however, influenced by physical vigor and rate of metabolic activity. Moderate muscular work or exposure to cool air augments metabolism and at the same time increases hunger. The young animal, who is metabolizing (*e. g.*, burning food as body fuel) more rapidly and therefore uses more food in proportion to its size than does the older one, also feels more keenly the hunger pang. Again, one may be much more hungry coming home at midnight after the theater (say five hours after the conclusion of the evening meal) than he is before breakfast the next morning (say twelve hours after the conclusion of the last meal); presumably because, in the latter case, metabolic activity is not yet in full swing for the day, and so the hunger contractions can not attain their maximum. And yet, pleasurable appetite sensations connected with the anticipation and appearance of a good breakfast, may lead to the taking of a hearty meal, even though the individual on arising was not aware of any special hunger pain or discomfort.

Not all food materials, however, are valuable to the body in proportion to the appeal which they make to the appetite. For example: the flavor substances in foods which stimulate the olfactory and gustatory nerves and thus give rise to appetite, are not ordinarily the sub-

stances upon which the body depends for its fuel, nor for the great bulk of its building materials. These latter materials—proteins, fats or oils, and carbohydrates (*i. e.*, sugars and starches), when chemically pure, have little or no taste or smell. (Sugars and various mineral salts are of course exceptions to this statement.) But so long as flavor bodies accompany nutritive substances, as is the case in most of the animal and vegetable tissues which man has appropriated for his food, the facts just stated are without much practical significance. When these tissues have undergone manipulation which divorces flavor bodies from nutritive substances, the case is quite different. For instance, in the use of boiled meat, appetite leads us to prefer the broth, which contains most of the flavor bodies (except those which may have escaped into the air with the steam), but which has practically no nutritive value, unless quite greasy; and to reject the tasteless meat, which contains 96 per cent. of the protein; very likely we also skim the soup to remove most of the fat, which is a highly concentrated form of fuel.

The preference for thin and crisp rather than greasy bacon is another illustration of the same thing. In a recent experiment it was found that of the 129 calories which represented the fuel value of a very thin 20 gram (three fourths ounce) slice, only 9 calories remained when the slice was sent to the table; 120 calories being represented by the fat which "fried out" into the pan. In this case a considerable amount of flavor body also goes into the fat, yet most persons would not consider eating it unless it has been skilfully blended with large quantities of other foods; whereas the scrap of skeleton tissue which has lost 93 per cent. of its food value is a dainty morsel.

Many more illustrations might be given to show the great and often inordinate changes in food value of our dietaries, due to some special, sometimes even erratic demand for what the individual has been led to consider a satisfactory flavor or an agreeable texture. These demands are apt to be particularly conspicuous and variable with individuals who are sedentary workers of the middle and upper classes, who live mostly in stagnant indoor air, whose muscular tone is usually low, with relatively feeble hunger contractions. For their appetite sensations, through the development of keen discrimination made possible by the wide choice of foods now offered, even to those of very moderate means, may be exceedingly acute, though their actual food requirement is relatively low.

Let us enumerate several instances of the lack of correspondence between popular demand and actual food value. The sauce made from dried fruits is usually much higher in fuel and even in protein than are the fresh fruits, but the latter are commonly preferred for their more delicate flavor; whether they have any further advantages over the dried fruits (possibly in the presence of the still mysterious

vitamines, or substances of kindred importance, destroyed by heat and drying?) is another matter. Similarly, dried beans and peas as ordinarily cooked will have from two to three times the food value of young green ones. In a general way the same thing is true of most vegetable foods and of many meats. In the case of meats, texture is considered to be of equal importance with flavor, or sometimes of greater importance—as when tenderloin is preferred to the higher-flavored round steak. Yet the tougher cuts of meat are quite as nutritious as the higher-priced ones; and, it may be remarked in passing, can be cooked tender with the development of good flavor and without losing their nutritive value. Price is a rough index of demand; oysters at 50 cents a quart, which is about $2.25 for one thousand calories, or 56 cents for one ounce of protein, are very likely to be preferred to boneless salt codfish at 10 cents a pound, which is 20 cents per thousand calories or 2½ cents for one ounce of protein. Or grapefruit (at 10 cents for the pound size), costing 60 cents per thousand calories, are often selected rather than apples (at 30 cents a peck), which yield a thousand calories for 12 cents. There may be no reason whatever for reversing the choice in either instance, but the justification sometimes urged by the extravagant housewife, that she must have "the best" in order properly to nourish her family, is likely to be without foundation; unless a question of sanitation or digestibility may be involved, as is occasionally the case.

Besides the fact that not all food materials are valuable to the body in proportion to the appeal which they make to the appetite, we must consider the great and often irrational variations to which this faculty is subject. No other bodily sensibility, perhaps, is so easily influenced by habits and customs and conventions, by personal idiosyncrasy and prejudice, by connotating circumstances, by suggestion of every sort, by the emotional complexion of the momentary mood; none, as a rule, so highly susceptible of education. Racial, sectional, religious, social, family, individual experiences—they all have a vote in determining my ideas of what I should have to eat. So, too, does the historical era, the geographical area, in which I live. The skilfulness of my cook may have the largest "say" of all; if she does not prepare vegetables so that they are appetizing, I shall probably eat more meat, bread or fruit, though none of these is an interchangeable substitute for any other. Convenience, the cost of living, and food legislation are sometimes large factors; city life does not conduce to hearty luncheons nor even breakfasts; rich country cream on my oatmeal adds 90 calories to my breakfast over the 18-per-cent-fat-by-order-of-the health-department cream I usually get at my city boarding-house. Varying physiological conditions may act irrationally, as on the hot summer day when I take ice-cream (very likely a more concentrated food than meat) solely for its cooling effect; or when in the midst of the afternoon's

shopping I buy tea and cakes in order to get a chance to sit down for half an hour.

It is evident that many of these factors mentioned above have no conceivable relation to my bodily requirement for food, which is determined chiefly by my age and stature, the amount of muscular work I do, my general nervous and muscular tone, my exposure to cold. Digestibility of food materials and conditions which favor good digestion are essential. Yet it appears that the importance of the enjoyment of food to secure favorable psychic influences upon digestion has been considerably overestimated, since men forcing themselves for experimental purposes to live upon a diet so monotonous as to be repugnant in the extreme, digest it in normal fashion; and similar results usually obtain with forced feeding of animals.

Any condition of food materials causing them to resist digestion will reduce their availability, and in proportion to the delicacy, sensitiveness or robustness of the individual digestive mechanism. The nutritive value of bran biscuits, or of rich pastry, may be zero for some persons, though both protein and fuel values of these two articles are very high when they are fairly well digested and assimilated.

An important factor in determining the nutritive value of the dietary is due to a tendency frequently observed toward large use of "manufactured" or commercially manipulated food materials, and to elaborate blending of these materials by the cook into rich and sweet desserts and other "made dishes," which, though high in fuel value, may very likely be lacking in some of the essential body constituents. Modern processes of food manufacture frequently result in the preparation of highly concentrated food materials—sugars, starches, fats and oils, various dried preparations—whose functions, when they are taken into the human organism, alone or in artificial combinations, are specialized and limited, and whose effects upon the instincts of hunger and appetite may easily be out of all proportion to their useful functions; *e. g.*, starch is isolated from the potato, from maize, from a dozen other sources; fat is isolated from milk as butter, from pork as lard, from the olive as oil. Sugar, a carbohydrate taken from sugar cane, beet or maple, is consumed in enormous and ever-increasing quantities; a recent estimate by a federal authority places its daily consumption at one fourth of a pound per capita, for the well-to-do classes, which would cover 450 calories, or almost 20 per cent. of the total food requirement of the adult sedentary worker, and a larger proportion of the child's requirement. The obvious reason for its popularity is not that it is a concentrated form of body fuel, but that it has a pleasing effect upon the palate (very similar, it happens, to that of saccharin, which has no food value whatever); therefore it is mixed with a large number of other foods. I add "a teaspoonful or two" of

sugar and two or three tablespoonfuls of cream to my saucer of sliced peaches—to be more exact, let us say from three fourths to one ounce of sugar and two ounces of cream to five ounces of peach slices—and consider that I am eating peaches flavored with sugar and cream. It would present the facts much more exactly, from the quantitative point of view, if I should say that I am eating sugar and cream flavored with peaches. For the sugar as fuel is worth 113 calories an ounce, and the cream 108 to 144 calories (according with butter-fat content of 18 per cent. and 25 per cent., respectively; rich country cream runs higher), the peaches are worth 59 calories, or about 20 per cent. of the fuel value of the whole combination.

In cooking fruits, particularly the sour or tart flavored ones, this enormous increase of food value by sugar added for the sake of improving flavor is intensified. The cherry pie which serves six, requires for filling, let us say, five sixths of a cupful of sugar to a cupful of cherries; *i. e.*, seven and a half to eight and a half ounces of cherries worth about 170 to 190 calories, with six and two thirds ounces of sugar, worth 756 calories. The crust of this pie presents another example of combination of concentrates. One half-pint cup of flour (which will be anywhere between one fourth and one third of a pound) is combined with lard or other fat (one twelfth to one half of a pound, according to recipe used) and a small amount of water (two to four tablespoonfuls), then baked until it loses an amount of moisture equal to from 20 per cent. to 35 per cent. of its total weight. This gives the entire crust a fuel value of 700 to 2,200 calories. If we use only a moderately rich crust, and add to the filling an ounce of flour (100 calories' worth) and one of butter (218 calories' worth), we shall have a value of 430 calories for each serving of 3 ounces weight (one sixth of the entire pie). About 30 of these calories are due to the cherries, the other 400 result from the added concentrates (35 per cent. from the fat, 31 per cent. from the sugar). Had the cherries been served as fresh fruit without sugar, a liberal serving of whole cherries would be three and one half ounces, worth some 74 calories; pitted, from three to five ounces (69 to 115 calories) makes a good showing, and most persons would add half an ounce of sugar (57 calories), or some would like twice that amount. As sauce, four ounces would make a good serving; that weight represents four and one half ounces of pitted fresh fruit (103 calories' worth), which would cook down almost to three ounces and would require the addition of at least three fourths ounce of sugar (85 calories), for cooking fruit "brings out the sour taste," and adds to the demand for sweetening. The value of a four ounce serving of the sweetened sauce is then at least 196 calories.

Not many of us would care to consume two ounces of sugar (about seven lumps, or four to six leveled tablespoonfuls) for breakfast with-

out the aid of flavoring materials; yet an ounce on half a grapefruit, half an ounce on breakfast cereal, and one third ounce (one lump) in coffee, are very moderate estimates of the amount eaten by the average person. This addition of 226 calories to the breakfast would easily be doubled by persons with a sweet tooth, and the consumption of a small tablespoonful of marmalade or syrup would mean another hundred calories or more, most (or all) of which are due to sugar.

It is true that sugar is a valuable fuel food, but it is far from being able to supply all, or even a large proportion, of the food requirement. When eaten as it occurs in nature—in fruits, many vegetables, in sugar beet and cane and maple sap—it is taken in comparatively dilute form, and the plant tissue in which it occurs helps to supply small but not altogether unimportant amounts of other food substances which should accompany it, but which are cast aside as impurities in the processes of manufacture. When the sugar is taken in the "pure" or concentrated form—as, for example, in the unhygienic performance of which two school-girls with a half-pound box of candy between them are capable—it has a well-known cloying effect, so that it replaces to an undue extent other needed food principles; or if not, then it contributes to over-eating, that evil so highly prevalent (when a sound digestion permits) in the well-to-do sedentary classes. For the extra sugar adds unnecessary fuel, without being able entirely to replace protein or at all to replace mineral salts as body building material, and without being able to do the work of vitamines, organic acids or bases, and other necessary regulatory substances.

In other words, our fashions in cooking and eating are often too intensive in respect to certain preferred concentrates. No wonder the cry is raised by faddists (and by others) concerning the dangers of "denaturized foods." These statements are not, however, to be taken as an argument against the use of prepared sugars, starches and fats; but as a protest against allowing the dishes made from them to replace wholly such foods as fresh fruits and vegetables. These latter are lower in fuel value, but contain needed mineral salts, organic acids, "vitamines," etc., which are very likely lacking in the rich pudding, flaky pastry, or sweet sauce or confection.

The one factor which ordinarily predominates over others in satisfying the eye and the judgment as to the amount of food required, which brings on the sense of satiety, which prevents the early recurrence of hunger, is, naturally enough, bulk. Yet it is not bulk, but weight and appropriate chemical composition, which determine nutritive value. The result is that when bulk is especially high or low in relation to weight, or when either is due largely to substances edible but not nutritious, the uncritical consumer is likely to vary his allowance widely, without being aware of the fact. To take an illustration

from breakfast cereals: In an ordinary two or three course meal, most persons would perhaps agree that an ounce and a half of any dry, granular, ready-to-serve breakfast food (two or three generous tablespoonfuls) would constitute a reasonable portion; whereas in the case of a dry flaked cereal, the same weight would go far towards filling a pint measure; could hardly be served in the bowl which would be suitable for most cereals, without refilling; and would probably be rejected by most persons as being an unduly large portion; indeed, half that weight would be a more acceptable serving to most. The discrepancy in food value between two such servings of these foods is, then, more than 100 per cent.

Again: In the case of cooked breakfast foods, we have a similar contrast with the more concentrated cereal served in its dry granular form; although the serving of mush or porridge may weigh from three to five ounces or more, most of that weight is due to water taken up in the cooking, and the amount of dry cereal represented in a serving is perhaps from one half to three quarters of an ounce.

The appraisal of food values on page 566 for two apparently similar breakfast menus illustrates again the influence of accessories (cream, butter, sugar) upon food values, as they help to double both protein and fuel figures for the second breakfast. It is to be noted that hot muffins usually "take more butter" than does toast, and toast more than does cold bread. Here is also illustrated the contrast in food value between a watery (cooked) and a concentrated cereal; a contrast still further enhanced by the fact that these cooked cereals are usually eaten with a smaller amount of cream than are the dry ones. Again, the psychology of serving is interesting; many persons who "could not possibly eat two eggs for breakfast" when the boundary line between eggs is plainly to be discerned, will nevertheless find a one-egg serving of scrambled egg rather too small; so that many housewives prefer to allow an extra egg or two in making the family dish. Serving a chicken presents similar problems; two two-and-one-half-pound chickens carved at the table may "go further" than one five-pound chicken, not because they furnish more meat (very probably they actually furnish less) but because they furnish a greater number of cuts which can be served.

But since this "natural instinct" or "normal appetite for food" has brought the human species thus far and safely through the long records of history and biology, why should any one now contemplate its abandonment, even for a moment?

To answer this question, let us consider these four propositions:

1. The preservation and improvement of the human species as a whole, and of its individuals, has come to depend upon very different factors from those which governed its welfare when the laws of this

BREAKFAST I

	Weight in Oz.	Protein, Grams	Calories[2]
Cantaloupe (with rind, 16.4 oz.) without rind	6.6	1.4	93
Corn or wheat porridge (uncooked, ½ oz.), about	4.44	1.54	51
Cream, 25 per cent. fat	1.43	1.08	100
Sugar	0.50		57
	6.37	2.62	208
Toast, 3 slices (thin; bread untoasted, 1.48 oz.)	1.10	3.90	109
Butter, 1 pat	0.50	0.14	109
	1.6	4.04	218
Egg, poached, 1	1.57	5.90	65
Butter, 1 teaspoonful, about	0.25	0.07	54
	1.82	5.97	119
Coffee, ⅜ pint	6.35		
Cream, 25 per cent. fat, 1½ tablespoonfuls, about	1.00	0.76	70
Sugar, 3 level teaspoonfuls or 2 small lumps	0.50		56
	7.85	0.76	126
Total breakfast	24.24	14.79	764

BREAKFAST II

Sliced peaches	5.00	0.98	57
Cream, 25 per cent. fat	2.00	1.52	140
Sugar	1.00		113
	8.00	2.50	310
Wheat grits of some kind, ready-to-serve	1.50	4.81	156
Cream, 25 per cent. fat	2.50	1.90	175
Sugar	0.50		57
	4.5	6.71	388
Muffins, 2	3.0	8.25	275
Butter, 1½ pats	0.75	0.21	163
	3.75	8.46	438
Scrambled egg:			
Eggs, 1½ per serving	2.36	8.85	98
Milk, 1½ tablespoonfuls, about	1.25	1.16	24
Butter, 1 teaspoonful	0.25	0.07	54
(Cooked weight 3.56 oz.)	3.86	10.08	176
Coffee as above	7.85	0.76	126
Total breakfast	27.96	28.51	1,438

2 These calorie values have been obtained by the use of Atwater or Sherman factors, chosen to allow for average losses of food not digested. These factors are, 4 calories per gram for proteins and carbohydrates, 9 for fats.

inherited instinct were evolved. The "survival of the fittest" involves the extermination of what we may charitably denominate "the others." But the nobler elements of modern human sentiment demand the protection, not to say the cherishing, of the unfit; who thus survive and hand on their legacy of ill adjustment to another generation. Furthermore, in these days of the supremacy of certain qualities of gray matter, such as shrewdness and "business faculty," and of human tools, the industrial (non-human) machines, it is far from being the case that the man who is muscularly fittest has the best immediate chance of survival, even if we leave all the works of human altruism out of consideration. By various means is the inevitable punishment for physical degeneration greatly delayed; and so vital a matter as a lack of adjustment of fuel or building material to body requirement, in spite of its ultimately more or less serious consequences, may go long with little remark. For instance, where in the "state of nature" does one find an over-fat animal? The struggle is too keen, to permit such to survive. Yet the over-fat human is by no means an uncommon phenomenon.

2. Furthermore, the fact that serious and rather common errors in nutrition are considered by physicians as important contributing causes to diseases which usually develop in middle life, and which result in long morbidity of insidious development lacking in the spectacular element produced by sudden mortality—this fact of the long delay of punishment tends to obscure the nature of the error. It is true, however, that having accomplished something toward the conquest of bubonic plague and cholera, typhoid and even tuberculosis, we are beginning to ask ourselves why it is that certain diseases are so constantly on the increase. For answer (in part, at least), it is more and more frequently mentioned to us, that overfeeding, that is, feeding too much protein, or too much fuel, or both, is often a predisposing factor of some importance in such cases as these: kidney and gall-bladder infections and inflammations, certain kinds of disturbance of the circulatory system (*e. g.*, arteriosclerosis, high blood-pressure diseases), various infections of skin or mucous membranes (from a common cold to the most serious eczema cases), and even possibly cancer.[3]

3. The voluntary muscles, which in the activities of the human animal in a "state of nature," use probably 75 per cent. of the fuel

[3] The author does not wish to be understood as making the claim that these diseases—*e. g.*, gall-stones, Bright's disease, diabetes, etc.—always, or often, have overeating as a sole or chief cause, even though it is so frequently mentioned as one of the causes. It must be remembered, too, that most points regarding the relation of diets to disease are still more or less in the controversial stage. Moreover, it must not be forgotten that the dangers of under-nutrition (especially in persons under 30 years of age) are equally serious with those of overeating.

which the body requires, have in this last century had their activities suppressed and curtailed as never before; this is true not only in sedentary (business or professional) but also in large sections of the industrial classes. We should expect, then, that the traditions, customs, and "instincts" of the frontiersman, the hard-working peasant, the soldier, who use from 4,000 to 6,000 calories' worth a day when they can get it, and need it all, may not necessarily prove a wise guide in the matter of food consumption, for their descendants, the bookkeeper, the broker, the skilled artisan, the factory hand, whose requirements are 2,500 to 3,000 calories a day. Hunger may be diminished by lessening muscular work, but appetite is not necessarily so; indeed, it seems that nerve-poisoning and heightened irritability resulting from overstrain and unhygienic indoor living may sometimes unduly heighten (instead of interfering with) the appetite for food; this is also the case with the other appetites, sensibilities and cravings of a "nervous" person, in many instances.

4. The changed condition of food materials due to the excessive utilization of high concentrates and to the use of artificial flavorings, has already been discussed; as has also the inadequacy of an inherited instinct satisfied by bulk in the stomach, for limiting the amounts of these concentrates which should be eaten.

The discrepancies, then, which are so frequently to be observed, between food requirement and food consumption, may be explained as due in part to present lack of adjustment to recent and enormous changes in environment and human activities and in the nature of foods. It seems quite possible that adaptation of diet to the activities of the organism, and other important hygienic measures, may come about, not simply through the slowly accomplished downfall of degenerate classes and nations, which history has so often shown us—for neither the rich fruits of shrewd business capacity nor the activities of the altruistic can ultimately shelter physical deterioration—but through the further discovery of the principles of scientific management of the human organism, and through the apprehension of these by the enlightened classes and the consequent practise of them by the world's population. Should we, indeed, expect the scientific intelligence to accomplish so much less striking results in the study of the structure and conduct of our own machine, than in that of the simpler non-living machines? Is it reasonable to assume that the laws of scientific feeding which man has already begun to apply with some success to other animals, will fail to produce results with the human species itself?

THE PSYCHOLOGY OF WAR

BY DR. D. E. PHILLIPS
UNIVERSITY OF DENVER

MY intention is not to discuss the causes, economic or political, of the present incomprehensible conflict in which some of the leading nations of the world are each unconsciously committing suicide. Neither do I intend to attempt a justification or condemnation of any of the parties now in arms. I seize this opportunity of trying to convince the public that the forces that move humanity are so deep and so subtle that we are constantly substituting surface and relatively unimportant causes for the deeper and real causes.

Spencer long ago showed that every form of human conduct has its roots and earliest manifestations in primitive man. Even human sympathy, the only force on which the anti-war spirit can safely build, and the only one that has wrought any inner change for real humanism, is not absent in the lowest savages.

However, it is not enough to say that war is founded on human instincts as old as the race. Many then jump to the conclusion that man is hopelessly doomed to war until the Judgment Day. Of course we are, if we properly understand the Judgment Day. Does not every organism struggle to live and to live at any cost? But you say: "Do people really war to live?" Not in this day. This impulse is joined with other impulses. There is an instinct of pugnacity manifested in nearly all people. You explain this in yourself as "righteous indignation." It is all right for us to fight, but never right for our enemy to fight.

Again, can we not trace everywhere the human impulse to excitement, to adventure, to insatiable achievement, to deeds of daring? There is also the instinct of emulation closely allied to the instinct of imitation. Perhaps the early forms of emulation are akin to the powerful forces of envy and jealousy, known to animals and common to all mankind. Race hatred is surely an instinct.

Nearly all individuals and all races have been dominated by the instinct of revenge. Let even a hereditary defective kill some of your friends, and then stand by and watch the course of vengeance. It is still not unlike savage vengeance. The life of the criminal is demanded on the respectable objective grounds of the good of society, but uppermost in the heart of the offended is vengeance. The savages always avenge any wrong done any individual of their group by indiscriminate punishment of the whole tribe. This is war. Later, this

punishment was, as we see in the Bible, limited to the family of the offender. Furthermore, vengeance is one of the most permanent of all feelings. It may last for years, and even be instilled in the coming generation. But the most remarkable thing is the extent to which vengeance passes as justice. Half of our cries for justice on our enemy are nothing but vengeance.

Finally, one more instinct should be mentioned—fear. Fear is the stamp of the coward. But the coward that fears to-day may fight to-morrow, because continued fear is the worse of the two evils. When fear is once turned loose it is cruel beyond measure. When Schiller was analyzing the human heart to find the most ungovernable, the most "don't care" emotion of man, he pointed out terror as that emotion. Terror is fear gone mad.

The manifestation of these instincts of economic possession, to have and to hold, of pugnacity, of self-elation, of achievement, of imitation, of envy, of jealousy, of race hatred, of fear, of vengeance, cooperating to the same end, through a few million years, have developed habits and customs that carry these forces beyond their aims and continue them in operation even when the grounds for operation have disappeared. When joined with intelligence, the instincts develop the most powerful forces of human society—sentiments of superiority, of egotism, of love and hate, of patriotism, of economic dominance or morals, of honor. Each age or peoples of the same age, who have developed different sentiments, pronounce damnation on all others. Here, and not in the intellect, is the foundation for all the divergent and dogmatic claims about justice, right, human welfare, etc. Such interpretations and claims are chiefly based consciously or unconsciously upon what the individual or nation feels to be of most vital personal interest.

If any one could make a careful diagnosis of all the forces operating in producing the war spirit in the United States to-day, he would find every one of these forces at work on the people of our country, even down to the contradictory absurdity of imitating Germany. We are only dimly conscious of the most powerful forces that move society.

While war is by all odds the dominant rule with savages and primitive peoples, there are those who rarely if ever engage in war. It is also true that there are other instincts, impulses and sentiments that have always been developing in opposition to these forces that make for war. To claim that might, and might alone, makes right is certainly a one-sided view. It is equally wrong to claim that might has nothing to do with making things right. No small part of our international laws have been directly or indirectly dictated by the most powerful. Truth, honor, justice, beneficence and love of mankind have been developed largely through human intelligence, but they are nevertheless founded on fundamental instincts, and most generally their interpre-

tation and application are mixed with all the instincts connected with war.

I in no wise minimize the place of intelligence in the mighty march of what we call civilization, but it has always followed the lines mapped out by instinct, impulse and human sentiments. Why do we not all abandon war? Every form of human intelligence is against it. Why do we not abandon our ancient and barbarous system of treating criminals? Psychological, biological and sociological sciences are against it. Simply because the accumulated forces of opposing instincts and sentiments are not yet strong enough to overcome the massive accumulation on the other side.

Such a well-known authority as McDougall, speaking of Central Borneo, says in his "Social Psychology":

> . . . villages and tribes live in a state of chronic warfare: all are kept in constant fear of attack, whole villages are often exterminated. This perpetual warfare seems to be almost wholly and directly due to the uncomplicated operation of the instinct of pugnacity. If one asks of an intelligent chief why he keeps up this senseless practise of going on the warpath, the best reason he can give is that unless he does so, his neighbors will not respect him and his people. How shall we begin to understand the prevalence of such a state of affairs, if we regard man as a rational creature guided only by intelligent self-interest, and if we neglect to take account of his instincts? And it is not among barbarous or savage peoples only that the instinct of pugnacity works in this way. The history of Christendom is largely the history of devastating wars from which few individuals or societies have reaped any immediate benefit, and in the causation of which the instinct of pugnacity has played a leading part. In our own age the same instinct makes of Europe an armed camp occupied by twelve million soldiers, the support of whom is a heavy burden on all the peoples; and we see how, more instantly than ever before, a whole nation may be moved by the combative instinct—a slight to the flag, or an insulting remark in some foreign newspaper, sends a wave of angry emotion sweeping across the country, and two nations are ready to rush into a war that can not fail to be disastrous to both of them. . . . The Germanic tribes were perhaps more pugnacious and possessed of the military virtues in a higher degree than any other people that has existed before or since. They were the most terrible enemies, as Julius Cæsar found; they could never be subdued because they fought, not merely to gain any specific ends, but because they loved fighting.

All history affords evidence of this smouldering war-volcano. Hundreds of individuals said to me on the outbreak of hostilities in Europe: "Is it not awful, foolish, unchristian, and barbarous? Surely we could never do such an irrational thing." Since that time most of these same people have caught the war fever and believe we should take a part in the war. This is simply common psychology. At one time cool intelligence speaks, at another strong feelings. The outbreak of our own Civil War will illustrate this law. The lions of the north and south were fully aroused. Brother was ready to butcher brother in the name of justice and right. Ministers outraged every form of human

intelligence in an effort to justify antagonistic principles and to reconcile religion to war.

Out of primitive savage warfare modern militarism has developed. Until recently political power was inseparable from military power. In early society all adult males were warriors. The army and the community were one. Men had just two ways of getting a living—out of the soil and out of other men. In primitive society, hunting and warring were joined in one occupation. The war chiefs also became the political leaders, and even to-day the two are only partially separated. In many cases, the ruler, knowing the favor and prestige of the military position, makes sure that he is either the head of the army or that he indirectly controls the army. This is true in our own country.

Later, the development of intelligence and fear compelled tribes and nations to some kind of union. Failure in the war usually ended in suspicion and hate among the defeated allies, and victory meant a quarrel over the spoils. When the present struggle ends, you will realize that this law still holds good. But victory also meant some kind of a standing army to guard the possessions. So we have had the constant union of tribes, peoples and nations against others, with the universal development of a standing army.

Everywhere the development of a standing army for defense has sooner or later passed over into offensive operations. Thirty years ago Herbert Spencer pointed out this law with many concrete cases. He says in his "Sociology":

> Always a structure assumed for defensive action, available also for offensive action, tends to initiate it. As in Athens the military and naval organization which was developed in coping with a foreign enemy, thereafter began to exercise itself aggressively; as in France the triumphant army of the Republic, formed to resist invasion forthwith became an invader; so is it habitually—so is it now with ourselves. In China, India, Polynesia, Africa, the East Indian Archipelago, reasons, never wanting to the aggressor are given for widening our empire; without force if it may be, and with force if needful.

The causes for this universal tendency are many. A well-organized fighting force always calls for readjustment in other nations, and this in turn creates fear, suspicion, and a demand for enlarging our forces. There is no letting go. Soon suspicion deepens into alliances, these into readiness to strike before it is too late. In the meantime every power of science is being employed to perfect the system of organization. In the eyes of those employed, this military organization becomes the nation. Among the many articles in our magazines, from men of military and naval prominence, how many can you find that do not declare war a necessary evil and tell us that we must not expect it to end or even diminish? How insistent are their demands for increase of army and navy? This is what we know in psychology as the power of apperception. A man who lives constantly in one atmosphere can

only interpret everything through that influence. This is not peculiar to the warrior. It is the same with the minister, with the millionaire who justifies his existence as such, with the Russian who believes his government superior to all others. We blame no one for it. At the present hour the harsh and brutal accusations men are bringing against their brothers would largely cease if only we fully comprehended this principle and its power over human opinions. Is it probable that any officer can escape the conscious and unconscious influences of possible honor, promotion and victory that might result from war? You may minimize it as much as you please; but, if our present type of officers is immune to these and other appeals which would cause them to lead us into war, we have suddenly developed a type of man not mentioned in history.

In how far may envy, jealousy, desire for personal gain, race hatred, vengeance, etc., creep into our interpretations of moral law, moral truth, justice, honor, the weak brother, etc.? In how far do they dictate what peace with honor is? Of course, we are always asking such questions about other people's idea of good and right, honor and justice; but rarely ever apply the same examination to our own. In all such cases, it is alarming to observe how absolutely certain we are that our interpretations are the correct ones. Do we not know that neither prejudice, hate, envy, vengeance nor personal interest of any kind enters into our judgments? I insist that the attitude neither of the millionaire nor the socialist, of the saloon-keeper nor the minister, of the warriors nor the lovers of peace, of the English nor of the Germans, must be interpreted as insincere or hypocritical.

What is defensive warfare? Well, suppose we have a big army and navy. Suppose Japan allows some of our citizens to be murdered over the sea. It is defensive warfare to avenge the wrong? Is it simply active justice that duty compels us to perform, in which neither vengeance, jealousy, nor race hatred takes any part? Or, suppose the people of India begin to groan under the burden of foreign rule, would it not be easy to decide that in the interest of humanity, justice, right and of the weak brother, we should wage a war in defense of their liberty? In such events would not every one of the war impulses and instincts demand a part in our interpretation and application of justice, moral right, benevolence, humanity, honor, weak brother and defensive warfare? The so-called man of practical business affairs may laugh at our psychology and refuse to recognize the power of these things; but that only proves the alarming danger to which we subject ourselves in entering upon the war policy.

To intimate, as Mr. Garrison and other war writers do, that we shall have self-control, that we shall not follow the rule of passing from defensive to offensive preparedness, is to betray our common conceit

and ignorance of human nature. We do not see that present sentiments will gradually give way to others. We do not see how one step calls for another, and yet another. Do we not all boast as to how we should act if we were millionaires? How shall we best find out what we should do under such circumstances? The best way conceivable is to select a thousand or two who have become millionaires and see what the majority have done. We shall, in spite of our honest convictions conceived under present conditions, in all probability act like the people whom we condemn.

It would be difficult to find a more clear-cut contradiction between intelligence and feeling than is presented in our consideration of preparedness. We try to blind ourselves to the fact that such considerations are prompted by all the instincts and feelings that make for war everywhere. The most unreasonable and unlikely fears are everywhere presented as the basis of action. Parallels and analogies of the most absurd kind are evidenced everywhere, Everything is done to array sentiment against intelligence. We cry out: "Look at England and France! See their fate for not being prepared." Are we to infer from this that our military preparedness is to go beyond what theirs was? Prominent public speakers and magazines compare the intended preparedness to our necessity of police and to "guarding against burglars." Suppose other nations so adroitly called us burglars. We should immediately want to defend our honor. Even *The Outlook* goes beyond this and compares it to preparation against fire and to the subjugation of the citizen by the state. One writer compares it to the obedience which a switch produces in children. Are we to be the state with all other nations our obedient subjects? Under the influence of such wild analogies the whole nation may become war-mad.

The fundamental psychological facts are: We have been surprised, and our mental peace has been taken from us by the revelations of a preparedness so far surpassing ours that we do not see ourselves so much of a world power as we had imagined. In spite of our boast of moral strength, we repudiate our Christianity and admit that we must rely more on physical force than on moral power for our "place in the sun." It is an interesting panorama of moral contradictions. We can not see that such evidences of practical righteousness as the repeal of the Panama Canal Tolls Exemption Act will do more to keep us out of war than fifty battleships.

Our pride has been touched, our hate aroused, our jealousy kindled, our imagination set going. We want to be able to strike, not when we are invaded (who would wait so long as that?), but when our trade is interfered with, when any more citizens are killed on the high seas, and to liberate those whom we think outraged by other heartless people. We want our army and navy to speak in the councils of the world.

Six months ago we talked only of defending our coast. Now we are talking of defending the weak brother and protecting our honor. There is not a man in public life who could not go out and shoot some one down on the grounds of an offended honor. All of the warring powers are sincere in believing that they are fighting for justice, honor and self-preservation.

A congressman said to me the other day: "How are we going to defend ourselves when Germany has guns that shoot eighteen miles?" I said: "Suppose we make guns that shoot twenty miles, and she makes guns that shoot thirty miles. Suppose we build ten battleships and she builds as many, are we any better off? Does it not simply mean greater certainty of war and greater destruction when it comes? How is any one nation to know that she is the best prepared? If she did know that, how is she to know what combinations will be made against her? Must we not always expect the weaker ones to combine against the stronger ones?" Alas, the politicians will see none of these things. They are trusting to chance to modify events in the future. They look on at the military conditions in Germany with bitter criticism, but they can never be made to see that the gradual growth of militarism in this country can produce similar strong sentiments for war. They do not see that the very democracy on which they rely to save us from the destiny of other nations owes its perpetuation largely to its freedom from militarism.

They will not listen to such sound psychological advice as President Butler, of Columbia University, was reported as giving in the *New York Times* for October 18, 1914. He says:

> It is not each nation's desire for national expression which makes peace impossible; it is the fact that thus far in the world's history such desire has been bound up with militarism.
>
> The nation whose frontier bristles with bayonets and with forts is like the individual with a magazine pistol in his pocket. Both make for murder. Both in their hearts really mean murder.
>
> The world will be better when the nations invite the judgment of their neighbors and are influenced by it.

If war was such a psychological necessity in the evolution of man, why is it not so still? When the whole male population constituted the army, the weak, feeble and cowardly were the ones weeded out. Modern militarism has exactly reversed this process. Our wars leave the race to be replenished from the most unfit. In past times one race or tribe either annihilated or made slaves of the weaker race. Races are no longer exterminated or enslaved. Modern methods of warfare make war absolutely impoverishing to all parties, even to the victors. Suppose the Japs should want to take from us the Hawaiian Islands. How many lives and how much money are they worth? Are they worth a single battleship with a thousand soldiers that may go down

and the heartaches of a thousand mothers? If that is the way we are to value life so late as the twentieth century, we may well hope for Huxley's friendly comet that will wipe this world into non-existence.

The developing instincts and sentiment that were once too weak to oppose war have been steadily gaining ground. This makes conditions quite different from what we find in the early history of men. Nothing has been so much needed to allay hatred and to bring about a proper understanding of conditions as a psychological explanation of conduct in war. Right is a very slippery word, especially when it is applied to the criticism of others or to those whom we dislike. But you say: "Have not agreements made some things wrong and others right?" Yes, the first criminal laws of Pennsylvania made twelve crimes punishable by death, and at the same time England applied the death penalty to over two hundred offenses. How long will the agreement for the state to murder criminals driven by circumstances and heredity to their destiny continue to be right?

I am inclined to think that all our agreements about having a humane war are mistakes; because they delude us into believing that we are civilized and are civilizing war. Such persons should see the humor in the title of an article in *The Forum*—"Thou Shalt Not Kill" in War.

Both history and the study of human nature warrants us in giving as a general law that all the so-called civilized nations will act very similarly in war under similar circumstances. This is not saying that no nation has any moral superiority; but I do mean to say that our moral superiority is by no means what we constantly assume it to be. It would be too painful to cite all the historic proofs that come to mind. How common it is in daily life for us to say: "If I were in such and such a one's place, I should not do so and so." What we really mean is that with our present ideas, judgments and feelings we should do so and so. We do not figure on the changes that would come over us in these changed conditions. So long as the intellect has the right-of-way, the lately acquired forms of conduct and character of individuals and of nations remain comparatively stable. But when the older forms of instinct, custom and passions are aroused these are easily set aside. Only those who have studied history from the standpoint of human feelings, as Le Bon has suggested, can understand what it means to invade an enemy's country with bitter hatred in your heart and with all the brutal instincts that war arouses. Neither do we realize what it means to try to judge where hatred and enmity are involved. There never was a time when men so much needed to apply some psychological analysis to their own opinions, beliefs, condemnations and praise.

Finally, if war has been backed by a network of instincts and sen-

timents, if preparedness only hastens war and more of it, what is the psychological remedy?

1. I have emphasized the fact that from the beginning sympathy, tender emotions, humanitarian feelings, kindness, benevolence, love, truth and justice which is not all vengeance, have been accumulating a force in opposition to the other instincts. Selfish intellect could never establish insane asylums, hospitals, red cross societies, homes for the aged, care for cripples and defectives, and abolish barbarous systems of punishing criminals. It is this altruistic fund of feeling, augmented by every intellectual effort of man, on which we shall build our forts to storm the forts of militarism. It is slow, but the outlook is not discouraging. I admit that the militarists are correct when they say that physical force has always spoken louder than moral force; but I do not admit that it must or will always be true. Why can we not see that it is just that kind of thinking that has kept physical force dominant?

2. How shall this be brought about? The surest avenue that psychology knows is through the education of the people. Several years ago we undertook to educate the people in the dangerous effects of alcohol. The liquor interests were all unconcerned. But now, look at the result. Whenever we speak against war we are called idealists and dreamers. I am not deluded by any idealism. I have presented the cold facts that the war impulses are too strong for intelligence. There is no mathematical axiom truer than this: So long as the majority of the people or of those in authority think we must have war and prepare for it we shall have it. Shall you or shall you not help to keep it going?

But let us not be absurd and attempt to teach peace and militarism in our schools at the same time. The boy that wears a uniform and at the same time receives formal instruction in peace and good will to all mankind will always have enough war impulses surging in him to laugh at such contradictions.

3. Again, we shall move on with our already large and highly perfected organizations for peace even if military writers continue to say these efforts have amounted to nothing. Militarism must be overthrown from without; the masses of the common people must do it; and it must come first from democratic countries. The psychologist does not look for it soon, nor as the result of any convention of those dominated by the war spirit.

Let all the nations abandon their system of trying to rob each other by tariffs. Let the government take all our munition plants and manufacture munitions only for our own use. There is not one man in a thousand who, if he speaks from his heart and not from some council acts, will not say that the only proper neutrality at all times would be to sell munitions to none of the warring nations. Let us cease to as-

sume that nations are going to attack us. The fortunes of war are always staggeringly uncertain. Our military men can give us no more assurance of victory twenty years hence with five times our preparation than they could with just the preparation we now have. Let us cease to think we must fight—as the savage did—that our neighbors may respect us. Let the religionist stop quibbling and outraging his intelligence to find a sanction for war in the teachings of Christ. The Christian should either frankly admit the fallibility of the teachings of Christ or confess that he can not pursue war and at the same time be a follower of Christ.

I may not live to see these things come to pass. But militarism must die or all intelligent thinking men will become discouraged, if not disgusted, with all our boasting about civilization and Christianity. Sympathy, kindness, self-control, peaceable sacrifice must triumph over man's lower instinctive nature. Those who ring the bell should never be discouraged because they can not march in the procession. Be sure it will follow.

RATING THE SEVERAL SOVEREIGN NATIONS ON A BASIS EQUITABLE FOR THE ALLOTMENT OF REPRESENTATIVES TO A WORLD PARLIAMENT

By HARRY H. LAUGHLIN

COLD SPRING HARBOR, LONG ISLAND, N. Y.

THE ultimate evolution of a World Federation to preserve the international peace and to coordinate certain human activities involving international intercourse is—howsoever long its coming may be delayed—highly probable. But before the several nations of the world actually succeed in organizing such a government they must agree upon an *equitable formula* as a basis of representation to the legislative body. In the House of Representatives of the United States Texas has 16 representatives, Pennsylvania 32, and Arizona 1. This is based upon population—the *formula* agreed upon by the makers of the Constitution. The people of the whole United States accept this apportionment as a matter of course; but, if an *equitable formula* had not been agreed upon, it is quite certain that quarreling over the one problem of apportionment would be a cause of discord sufficient to vitiate the purpose of the whole Union. All will agree that the general judgment of any possible body of alloters, howsoever honest and well informed they might be, could not satisfy the constituent members of a federation with their allotments nearly so well as such members could be satisfied with their respective allotments resulting from a *mathematical formula* worked out in accordance with collected data.

In the United States the *population formula* works well, because in any given state the average American is about as intelligent, as prosperous and as patriotic as in any other state. But among the nations of the world there exists, as well as a great range in their participation in the world's work, a wide variability in the proportion-mixture of their elements of national greatness. In a constituent convention each nation would, therefore, strive to make its greatest quantitative asset a most important factor in apportioning representatives to the Parliament of Man. Most certainly this difference of opinion concerning the *proper formula* of representation will prove to be the first great stumbling block to progress in any constituent assembly actually intent upon working out a plan for the political organization of the world. Small nations will argue that all sovereign nations should be equally represented; yet equitability, not necessarily equality, is the only just basis of representation in governing bodies generally. When

TABLE I

ALLOTMENT TO WORLD PARLIAMENT: NATIONAL ASSETS EQUITABLY WEIGHTED

Basis:—

Rule A.

1. Land area potential to supporting civilization—all of the world's land, excepting the frozen polar and the arid desert wastes.........5%
2. Land area actually supporting civilization—all of the world's populated land over which law and order prevail............10%
3. Total population.....10%
4. Population partaking of the world's work—all persons reported as "literate" in census returns, and in other more or less authoritative estimates.........25%
5. Foreign commerce ...50%

Rule B.

1. Home territory of sovereign nations—full rate.
2. Autonomous colonies and semi-sovereign countries—half rate.
3. Non-autonomous colonies—quarter rate.
4. Each sovereign nation to have at least one representative.
5. Colonial and semi-sovereign country evaluations accredited to the mother or sponsor country.

Rule C.

1. Total number of representatives: 500.

	Sovereign Nation (Including Their Colonial Allotments as per Rule *B*)	Total Per Cent. Rating	Rating on the Basis of 500 Representatives	Major Fractions	Final Allotment of Representatives to the World Parliament
1.	British Empire....	.18491	92.459	—	92
2.	United States of America........	.13877	69.388	—	69
3.	Germany.........	.10202	51.013	—	51
4.	Russia...........	.09772	48.863	1	49
5.	France...........	.08224	41.123	—	41
6.	Netherlands......	.04486	22.443	—	22
7.	Austria-Hungary ..	.04423	21.127	—	21
8.	China............	.03986	19.931	1	20
9.	Italy............	.03536	17.688	1	18
10.	Japan...........	.03019	15.097	—	15
11.	Belgium..........	.02869	14.347	—	14
12.	Brazil...........	.02505	12.525	—	12
13.	Spain............	.01803	9.015	—	9
14.	Argentine Republic	.01702	8.510	—	8
15.	Switzerland.......	.01175	5.886	1	6
16.	Sweden..........	.01121	5.608	—	5
17.	Mexico..........	.01097	5.486	—	5
18.	Turkey..........	.00929	4.647	1	5
19.	Denmark.........	.00623	3.120	—	3
20	Portugal.........	.00623	3.119	—	3
21.	Chili............	.00558	2.792	1	3
22.	Norway..........	.00521	2.601	—	2
23.	Rumania.........	.00486	2.434	—	2
24.	Cuba............	.00485	2.427	—	2
25.	Colombia.........	.00403	2.018	—	2
26.	Persia...........	.00357	1.788	1	2
27.	Peru............	.00263	1.307	—	1
28.	Bulgaria.........	.00249	1.250	—	1
29.	Bolivia..........	.00237	1.189	—	1
30.	Venezuela........	.00210	1.051	—	1
31.	Uruguay.........	.00195	.976	—	1
32.	Siam............	.00197	.937	—	1
33.	Greece...........	.00175	.880	—	1
34.	Serbia...........	.00165	.828	—	1
35.	Equador.........	.00094	.474	—	1
36.	Guatemala........	.00070	.354	—	1
37.	Paraguay.........	.00058	.294	—	1
38.	Salvador.........	.00057	.287	—	1
39.	Panama..........	.00050	.251	—	1
40.	Haiti............	.00049	.246	—	1
41.	Santo Domingo....	.00044	.221	—	1
42.	Costa Rica........	.00038	.193	—	1
43.	Honduras.........	.00030	.155	—	1
44.	Nicaragua........	.00025	.128	—	1
45.	Montenegro.......	.00013	.067	—	1
					500

Note.—This schedule does not include the results of the recent "*Balkan Wars*"—nor of course of the present "*Great War.*"

The area of the entire world is included under the above 45 sovereignties. The semi-sovereign nations were assessed at half rate and their ratings accredited to their respective sponsor nations.

These tables show only the summaries. The full details of the calculations are omitted for lack of space.

ALLOTMENT TO WORLD PARLIAMENT: BASIS OF TABLE I MODIFIED SO AS TO CAST NATIONS INTO POWER GROUPS

Rule.—Add the allotments (Table I.) of the first and the second nations; divide by 2. If the quotient is not at least twice as great as the allotment of nation No. 3, add the allotments of Nos. 1, 2, and 3; divide by 3 and compare as before with the allotment for the next succeeding nation (this time No. 4), and so on until the comparison shows a drop of at least 50 per cent. between the quotient and the allotment for the next succeeding nation. Assign to each nation whose original allotment entered the dividend an allotment equal to the quotient. Discard the remainder, then proceed anew with the succeeding nations.

	Sovereign Nation	Final Allotment of Table I	Calculations	Final Power Group Allotment	Compared with Table I
1.	British Empire....	92	302 + 5 = 60 + *5 First-Rate Powers.*	60	Loss, 32
2.	United States of America........	69		60	Loss, 9
3.	Germany.........	51		60	Gain, 9
4.	Russia...........	49		60	Gain, 11
5.	France...........	41		60	Gain, 19
6.	Netherlands.......	22	122 + 7 = 17 + *7 Second-Rate Powers.*	17	Loss, 5
7.	Austria-Hungary ..	21		17	Loss, 4
8.	China............	20		17	Loss, 3
9.	Italy............	18		17	Loss, 1
10.	Japan............	15		17	Gain, 2
11.	Belgium..........	14		17	Gain, 3
12.	Brazil............	12		17	Gain, 5
13.	Spain............	9	38 + 6 = 6 + *6 Third-Rate Powers.*	6	Loss, 3
14.	Argentine Republic	8		6	Loss, 2
15.	Switzerland.......	6		6	—— 0
16.	Sweden...........	5		6	Gain, 1
17.	Mexico...........	5		6	Gain, 1
18.	Turkey...........	5		6	Gain, 1
19.	Denmark.........	3	19 + 8 = 2 + *8 Fourth-Rate Powers.*	2	Loss, 1
20.	Portugal..........	3		2	Loss, 1
21.	Chili............	3		2	Loss, 1
22.	Norway..........	2		2	—— 0
23.	Rumania.........	2		2	—— 0
24.	Cuba............	2		2	—— 0
25.	Colombia.........	2		2	—— 0
26.	Persia...........	2		2	—— 0
27.	Peru.............	1	19 + 19 = 1 *19 Fifth-Rate Powers.*	1	—— 0
28.	Bulgaria..........	1		1	—— 0
29.	Bolivia...........	1		1	—— 0
30.	Venezuela........	1		1	—— 0
31.	Uruguay.........	1		1	—— 0
32.	Siam............	1		1	—— 0
33.	Greece..........	1		1	—— 0
34.	Serbia...........	1		1	—— 0
35.	Equador.........	1		1	—— 0
36.	Guatemala........	1		1	—— 0
37.	Paraguay.........	1		1	—— 0
38.	Salvador.........	1		1	—— 0
39.	Panama..........	1		1	—— 0
40.	Haiti............	1		1	—— 0
41.	Santo Domingo....	1		1	—— 0
42.	Costa Rica........	1		1	—— 0
43.	Honduras.........	1		1	—— 0
44.	Nicaragua........	1		1	—— 0
45.	Montenegro.......	1		1	—— 0
		500		490	

The data for the calculations were taken largely from "The Statesman's Year Book."

the geographical units of a federation are inhabited by persons of nearly equal, howsoever different, average attainments total population has proved to be the simplest and fairest basis of apportionment; but the individual human units of the world's civil units are by no means equal in their participation in the world's work, hence total population would not be a fair basis of apportionment of legislative voice among nations. To a proposal to make it such China would answer "Yes"; Holland, "No." If foreign commerce were proposed, England, Holland and Germany might answer "Yes"; Italy and Austria-Hungary, in company with all of the smaller of the younger nations, would probably say "No." If area were proposed as the measure, Russia and Brazil would answer "Yes"; Switzerland and Belgium, "No." Shall colonies give additional weight to the mother country's allotment? Britain and Holland would answer "Yes"; Sweden, "No."

Granted that in a constituent assembly each nation would evince a genuine willingness to consider all of the elements of national greatness possessed by every other nation, nevertheless the tangle would grow, and the conference would end in confusion and discord, unless an *impersonal and mathematical formula* embodying their notions of justice could be found. Why, then, not weight the principal assets of national greatness in proportion to their bearing upon the world's work? The United States, in particular, can afford to be conciliatory in the attempt to reach an agreement by this road, for its faith in the federal idea, based upon experience, is sincere and clear, and its elements of national greatness, while quantitatively great, are harmoniously balanced, so that almost any just formula would give her about the same percentage of the sum total of the rating of all of the several sovereign nations.

The accompanying tables, one and two, represent an impartial effort to rate the nations of the world in national assets, giving due consideration to those factors which make nations intrinsically great and participatory in the world's work. Table three shows the unfairness of depending upon any one single national asset as a basis for rating nations for equitable representation in a World Parliament.

There should be secured from representative men of every profession of every nation and colony of the world the *formula* which each man individually considers *just* and would be willing to see his *own* country subscribe to. These formulæ should then be worked out in apportionment tables with as great accuracy as the obtainable data will permit. There are now in the United States a number of agencies working actively for the promotion of international peace and world government. Among them are the "Carnegie Endowment for International Peace," the "World Peace Foundation," the "League to Enforce Peace," the "American Peace Society," the "International Peace Forum," the "American Peace and Arbitration League Inc.," the

TABLE III

Other Schemes of Allotment to World Parliament

In each case: (1) Five hundred representatives. (2) Based upon *one only* of the five national assets which contributed to the allotment of Table I. (3) Based upon the asset of the *home territory only* of the sovereign nation, *i. e., not* adding the ratings of colonies and sponsored countries to their respective mother and sponsor countries as in Tables I. and II.

Nation No. and Rank in Table I	Sovereign Nation: Home Territory Only	Basis: Total Land Area Potential to Supporting Civilization		Basis: Total Land Area Actually Supporting Civilization		Basis. Total Population		Basis: Population Partaking of the World's Work		Basis: Foreign Commerce	
		Allotment	Rank	Allotment	Rank	Allotment	Rank	Allotment	Rank	Allotment	Rank
1.	Great Britain and Ireland	3.34	23	7.39	15	23.00	7	45.12	4	96.21	1
2.	United States of America	81.93	2	185.42	1	46.62	3	90.24	1	63.15	3
3.	Germany	5.74	15	12.72	7	32.65	4	56.40	3	69.64	2
4.	Russia	56.12	3	29.60	3	66.51	2	84.60	2	21.43	7
5.	France	5.70	16	12.62	8	19.96	8	33.84	6	46.14	4
6.	Netherlands	.35	41	.77	37	2.99	19	5.64	13	41.97	5
7.	Austria-Hungary	7.19	14	15.90	5	25.21	6	39.48	5	19.08	8
8.	China	42.21	4	12.18	10	152.08	1	11.28	10	5.49	16
9.	Italy	3.05	25	6.75	16	17.52	9	28.20	8	17.94	9
10.	Japan	4.83	19	10.70	12	25.73	5	33.84	7	8.16	13
11.	Belgium	.31	42	.70	39	3.59	15	5.64	14	26.40	6
12.	Brazil	88.67	1	60.95	2	10.88	11	6.77	11	9.73	12
13.	Spain	5.29	18	11.70	11	9.89	12	16.92	9	6.28	15
14.	Argentine Republic	31.28	5	15.24	6	3.54	16	3.39	17	12.58	10
15.	Switzerland	.44	39	.97	34	1.85	25	3.95	16	10.01	11
16.	Sweden	4.76	20	10.54	14	2.78	20	5.67	12	6.99	14
17.	Mexico	21.12	6	21.94	4	6.90	13	4.51	15	4.44	18
18.	Turkey	20.91	7	12.19	9	12.08	10	3.38	18	3.27	21
19.	Denmark	.42	40	.91	35	1.31	30	2.26	19	5.02	17
20.	Portugal	.95	33	2.09	26	2.36	21	2.26	26	2.03	24
21.	Chili	8.06	13	5.49	22	1.68	26	1.13	24	4.06	20
22.	Norway	3.42	22	6.62	17	1.21	31	2.26	21	3.12	22
23.	Rumania	1.40	27	3.09	23	3.48	17	2.26	22	2.97	23
24.	Cuba	1.21	31	2.44	24	1.09	32	.63	29	4.32	19
25.	Colombia	11.98	11	10.67	13	2.20	23	1.13	25	.23	35
26.	Persia	18.73	9	6.10	18	4.82	14	.34	35	1.32	26
27.	Peru	19.17	8	6.09	21	2.28	22	1.13	26	.09	42
28.	Bulgaria	1.04	32	2.32	25	2.17	24	1.69	23	1.05	27
29.	Bolivia	16.68	10	6.10	19	.93	35	.56	30	.59	30
30.	Venezuela	10.85	12	6.10	20	1.36	27	.56	31	.47	32
31.	Uruguay	1.98	26	1.83	27	.56	38	.29	36	1.54	25
32.	Siam	5.37	17	1.83	28	3.17	18	.23	37	.98	28
33.	Greece	.69	35	1.52	29	1.34	29	1.13	27	.82	29
34.	Serbia	.52	36	1.14	32	1.36	28	.79	28	.52	31
35.	Equador	3.20	24	1.22	30	.65	36	.34	33	.43	33
36.	Guatemala	1.33	29	.73	38	1.01	34	.56	32	.13	41
37.	Paraguay	4.72	21	1.07	33	.32	39	.17	40	.16	40
38.	Salvador	.20	44	.18	45	.57	37	.34	34	.23	36
39.	Panama	.86	34	1.21	31	.23	42	.23	38	.18	38
40.	Haiti	.27	43	.43	42	1.03	33	.23	39	.18	39
41.	Santo Domingo	.48	38	.91	36	.31	40	.11	42	.22	37
42.	Costa Rica	.50	37	.43	43	.19	44	.11	43	.24	34
43.	Honduras	1.27	30	.49	40	.25	43	.17	41	.08	43
44.	Nicaragua	1.36	28	.49	41	.21	42	.11	44	.07	44
45.	Montenegro	.10	45	.22	44	.13	45	.11	45	.04	45
		500.00		500.00		500.00		500.00		500.00	

Note.—The home territories of the sovereign nations of the world possess:

35.10% of the world's total area potential to supporting civilization.

52.87% of the world's total area actually supporting civilization.

61.72% of the world's total population.

92.47% of the total population partaking of the world's work.

80.91% of the world's total foreign commerce.

"American Society for the Judicial Settlement of International Disputes," the "New York Peace Society," the "Woman's Peace Party," and the "League for World Peace." Although most of them doubtless have their own programs of work, it is hereby proposed that they consider the desirability and the feasibility of collecting and working out a large number of apportionment formulæ. The value of a volume of 5,000 such tables properly classified and summarized, to the members of the next Hague Conference would be very great. Thus systematic canvassing and careful mathematical tabulation as well as direct educational propaganda would promote world federation.

OUR DUTY TO THE FUTURE

By C. E. VAIL, M.A.

ASSOCIATE PROFESSOR OF CHEMISTRY, COLORADO AGRICULTURAL COLLEGE

IN a certain western city a prominent portrait photographer has for many years used the slogan, "Preserve the Present for the Future." While his chief work, naturally, has been the preservation of the likeness of human beings, his advertising contains an appeal to the sentiment of his patrons that might well be the sentiment of all of us toward every worthy product of human endeavor.

There may be found in this slogan the germ of an idea that appears to have been given but slight consideration in our present age of hurry and worry, hustle and bustle, strain and stress. This idea may be expressed broadly as the desirability of making some definite effort to preserve our present-day knowledge, along with the best products of man's hand and brain, in a form that will endure as long as the Pyramids, or even much longer. With our present scientific knowledge and spirit, the glories of this age ought to be recorded and made intelligible to posterity in a manner that could be equalled or surpassed only by posterity. There should be a concerted effort and aim of living civilized men to preserve a representative portion of the present for the future.

There are probably few men in the scientific world who do not think it well worth while, and even necessary, to take an interest in some branch or branches of science outside of their own specialties. One may go even further and say that many scientific men take more or less interest in all sciences. While it may be nothing more than a guess, yet it may be stated as a probability that the majority of the readers of THE SCIENTIFIC MONTHLY belong to this latter class. If this is true, or even half true, it may be assumed that this article is addressed to a considerable number of men who are interested to a greater or less degree in the fascinating science of archeology.

The ephemeral, transient character of most of the present works and products of man is readily noted. What bearing will this fact have upon the future? Any person who is familiar with the work of the many enthusiastic, patient and long-suffering archeologists of the last sixty years will recall the problems and difficulties which have harassed these workers. While many most interesting and noteworthy discoveries have been made, they have cost much money, time and labor, and the best years of many worthy men. Let us ask ourselves if it is right that we, with our costly experiences in attaining what is at best but an imperfect knowledge of ancient civilizations, should be indifferent as to

the records we leave, or the lack of them. Is there not a possibility that the archeologists of the future will find it proportionately as difficult to obtain an accurate knowledge of our present civilization as our present archeologists have found it to learn about the past? It may be worth while to consider what our duty is in this respect to posterity.

In this discussion we may find it convenient to indicate the modern products of man's hand and brain, that have at present a permanent or recorded form, as "works." Those of the past might be referred to collectively as "ancient works." Before we proceed further in our argument, it might be well to examine the modes in which the works of man may be or have been destroyed. And by destruction we mean the state of ruin in which we have found many ancient works, as well as the utter ruin which leaves practically no trace or residue.

Most of the natural forces that appear to have accomplished the ruin of ancient works can be considered as being just as effective now as they have ever been. Possibly we should still consider man as an intentionally destructive agent, present world conditions being so closely analogous to those of the past.

The first natural agent that probably most readily suggests itself is vulcanism, with its accompanying or brother calamity, earthquake. One scarcely needs to enlarge upon the series of disasters of this character that have occurred within historic times. Nearly every year we still find that earthquakes and volcanic eruptions occasion great damage and loss of life somewhere on the earth. If a building is to withstand earthquake, it must be exceptionally well built, and its site and foundation prepared with some care. Or, on the other hand, the buildings have to be, like those in Japan, constructed of materials that may be destroyed by other agents, if not by earthquake. Vulcanism may be terribly destructive in several ways. One is by the burial of cities beneath great quantities of volcanic "ash," sand, lapilli, etc., as at Pompeii; another, by the flow of hot lava over and through the works of man; still another, by the swift discharge of large volumes of hot and poisonous gases, as at St. Pierre. One might almost say that more ancient ruins were caused by earthquake and vulcanism than by any other natural means.

Considering wind, water and fire, one may readily recall the known effects of these natural agents upon ancient works. Violent winds or tornadoes have doubtless visited man's habitations in the past as they have in modern times, and in their effects have been as destructive to certain structures as fire or earthquake. The Deluge of Biblical history seems to have been something more than a mere tale. Even the legendary continent of Atlantis may have existed as a large island or archipelago, finally destroyed by tidal waves and seismic disturbances. Floods and deluges are prominent in the folk-lore of peoples over nearly the whole earth. We moderns have had experiences with floods, tidal waves, and the like, which have shown us the destructive power of

nessed many an ancient work ruined or damaged by water, and here also the hand of nature was seen more often than that of man. On the other hand, destruction by fire has doubtless been occasioned much more often by man than by nature. Whether started by accident or by design, fire has ever been a terror to all peoples. While many ancient works were of a character to remain to a large extent unaffected by fire, yet some of the things most desirable for us to have known about were utterly lost, being readily combustible. It is certainly fortunate for us that such a large number of written records were made on stone, clay or metal instead of on so combustible a substance as papyrus. What would we not now give for manuscripts long since destroyed, as those in the famous library at Alexandria, or the Aztec writings burned by fanatical Spaniards? We are able to see, then, how these agents, the primitive elements, air, water and fire, have affected man's works in the past, and what may be expected of them in the future.

Still other natural forces deserve our attention. Among the most prominent of these are the two extremes, glacial and desert conditions. The destructive action of ice and snow is to be seen somewhere almost every season on a relatively small scale. But what of a frigid epoch like that of the Pleistocene when half a continent was covered with immense ice sheets? We only have to be reminded that in those times the destruction of nature's own works was enormous, in order to realize what might have happened to ancient works, and what may yet happen to our own works of to-day. Whether acting as glacier, iceberg or floe, ice must be reckoned with as a possible natural agent in destroying the so-called "imperishable" habitations and monuments of man. And with ice we must put the avalanche, a swifter but less powerful ally. One might also speak here of landslides, an agent of destruction that is not at all unfamiliar in many parts of the world.

The desert areas of the globe afford us some excellent examples of the effect of torrid and arid conditions upon man's works. The deserts are quite frequently areas of violent atmospheric disturbances with almost an entire lack of precipitation and consequent dearth of vegetation. The soil is sand, or alkali, or a mixture of these, and the winds keep the small dry particles in almost constant motion. Rock surfaces are soon cut, etched, and eroded to an astonishing degree by the force of nature's sand-blast. Is it surprising that there are but few inhabitants, and these mostly nomadic, in the desert places? Yet on the sites of several present desert regions there flourished in ancient times civilized peoples whose only relics that remain to us are a few ruins of stone buildings, a few mummies, some specimens of pottery, and a few metallic ornaments. The present Sahara desert was in recent geologic times the home of animals that subsisted upon abundant vegetation. The Desert of Gobi has overtaken and concealed cities

of the ancients, of which little remains but a few ruined walls. The coast of Peru, possibly as rainless a region as may be found, has beneath its sands the remains of a people of unknown antiquity. The remarkable ancient city of Petra is situated in a peculiar many-colored rock-walled valley in the midst of a desert. It was wholly lost to the world for over a thousand years. On our own Atlantic coast, and elsewhere, we can readily follow the sand dunes as they travel inland, burying and destroying forests and villages. The known work of the wind, aided by sand, especially in a rainless, tropical region, suggests a natural agent of destruction—an enemy of man's handicraft that may be expected to certainly overtake and destroy, somewhere, sometime, the objects of art and culture that modern man has so carefully and painfully constructed.

Finally, we might make mention of the part man has taken in accomplishing the destruction of the works of his brother. War, disease, pestilence, the torch, starvation, and like allies of savage man, have wrought great destruction of material things, either directly or indirectly. The effects of fire have been referred to. War, hand in hand with disease and starvation, has leveled and depopulated many a city and country, and most often the victors in war have removed their loot and carried off their slaves, leaving the works of the vanquished people to lie uncared for and in ruins. Sometimes the fortunes were reversed, where a race or tribe of people who had been taken captive eventually carried out a successful rebellion, returned to the sites of their former cities, conquered or drove away any foreign race, and built their cities anew. In the course of time these cities were cast down in ruins once more.

Innumerable questions arise in the tracing of the fortunes of many peoples whom we moderns know only by the ruins and relics we have found. When we inquire into the reasons for the disappearance of a people, or the discontinuance of their civilizations, we can not always be sure that the proper agent or agents have been selected, since in the end the effects of several different agents may be so similar. Who were the Mound Builders, the Cliff Dwellers, the Toltecs, the Mayas, the Pre-Incas, the Cambodians, the mysterious dwellers of Easter Island? What was the origin of each of these peoples? In most cases we do not even know when or why they disappeared, much less their history. Were they exterminated or forced to migrate by natural agents, or by a conquering race? Have their works fallen to decay as a result of nature's behavior, or has nature been assisted by the hand of man? Doubtless, these and all similar questions will be fully and definitely answered sometime. But are we to wait until that time arrives before we are moved to consider the history of these and all such races, and learn one of the most serious lessons such consideration has to teach us?

Our present-day museums contain many wonderful, curious, instructive and interesting objects. The museum is a real factor in education, and the vast amount of labor and money spent on these treasure houses of art, history, science and industry has been in most instances well spent. Further, the value of the exhibits and collections has increased with the passage of time. In fact, it is almost axiomatic that the further we become removed in time from the moment of its fashioning the more valuable an object becomes. In but few instances, however, can we be said to be taking definite action to "preserve the present for the future." We have by great diligence acquired some knowledge of man as he lived before our time, with some of his relics, monuments and works of art. We take great pains to transport and preserve Egyptian obelisks and tombs, Babylonian inscriptions, Aztec gods, and even Libby prisons and presidential birthplaces. What is the future of these? Will the coming generations fail to receive or acquire an interest in these things equal to our own? It would seem probable that there will be men five or ten centuries hence who will have an interest in not only their own national history, but also that of peoples who seem ancient or semi-ancient to us. It would seem that our duty to the future lies in not only preserving our own present-day relics, but also in leaving some adequate and authentic account of our own times with such illustrative material as may be considered necessary or desirable.

It seems almost needless to point out that we ought to be beyond leaving our records and relics to the future in any indefinite or haphazard manner. Yet if we ask ourselves what we have done or are doing to safeguard our historical treasures and works of art, what answer is to be found? Have we taken into account the possibilities? Suppose this country should be visited by some unprecedented and widespread series of disasters, originated by the forces of nature—what would be left? What is there that we now have that could withstand earthquake, vulcanism, tornado, tidal wave, fire, ice or sand dune? Suppose our museums and monuments escape one or several of these destructive agents, are they able to withstand all? What is there that we may really call permanent, that we may set up to defy all the forces of nature until the next geologic era?

Let us see if among the present known materials there may be found one that we may call the ideally resistant material. The rocks of the earth's surface have always appealed to man as the very essence of endurance, changelessness and permanence. In the stone age man learned that some rocks were very hard, dense and durable; that others were soft or brittle; that some rocks could be shaped by using pieces of harder ones, and polished by the powder of others; that some were adapted to the fashioning of weapons and implements, idols, inscriptions, and ornamental designs; that rocks resisted fire and the weather,

and afforded a shelter from heat, cold and storm, and a barrier to enemies. While man has since learned the manufacture and uses of other materials, he still seems to place his greatest faith in stone as a means of combining dignity, utility and permanence. The most famous and nearly the most ancient stone monuments are the Pyramids of Egypt. They have endured so long as to seem almost indestructible. But let the climatic conditions be altered to correspond with central Africa, or even the interior of the Sahara, and the Pyramids would be much less able to resist the forces of nature; their period of duration would be greatly shortened. Earthquake is perhaps the greatest destroyer of structures in stone, yet man has learned how to build, if he will, so as to withstand even violent earthquake shocks, as evidenced by the wonderful mortarless masonry of the Incas, in Peru, a land that certainly can not be said to be free of the peril of earthquake. Reinforced concrete is probably the best modern material that might be used to withstand earthquake shocks. The concrete work at Panama, a region that has seen considerable seismic disturbance, will probably afford us information as to its stability in due time.

It might be remarked in this connection that reinforced concrete seems to suffer but little from the effects of fire, unless the heat be exceptionally intense and prolonged. Many rocks, however, do not pass the ordeal of fire without becoming thereby more readily attacked by weathering agents. Granite, marble, limestone and sandstone, four of the most used building stones, endure heat rather unequally. Both marble and limestone are decomposed by heating, passing into ordinary lime. Digressing for a moment to the use of marble in ancient art, we are frequently struck by the lack of foresight, or of knowledge, of the ancient as well as medieval and some modern sculptors in choosing marble as the final expression of their art. Pure white marble is undoubtedly beautiful; but, supposing some vandal desires to satisfy his appetite for destruction by pulling down marble statues, shattering them by blows, or forever destroying them by fire? Modern artists never cease grieving over the incompleteness of many of the ancient masterpieces, known to us only in a fragmental or damaged condition.

Granite and sandstone may successfully withstand earthquake and fire, but they, as well as less stable rocks, can not be entirely free of the effect of vulcanism. The well-known effect of molten lava upon sandstone, changing it to quartzite, would be the final chapter in the history of an edifice of sandstone, overtaken by a lava flood. And in the case of either granite or sandstone, a lava flood would so fill and surround and alter the structure that it would be as good as lost forever. The earthquake and volcano belts of the earth have been carefully traced and defined, and are found to be practically identical in position. The association of earthquakes with volcanoes is very striking; but are we quite certain that these belts will always remain as they

are? Is there not a possibility of their shifting, very gradually perhaps, but nevertheless with a distinct movement, noticeable every fifth or tenth century? The question is one that can not be definitely solved. The belts will doubtless move together, but can we say that any given portion of the earth's crust will be forever free of earthquake or vulcanism?

Man seems to delight in building his cities as near to danger as possible. Witness the manner in which the peoples of the Mediterranean insist on staying by their volcanoes, and rebuilding their shattered cities. Taking an example at home, may not San Francisco run the risk, with other coast cities, of being destroyed once more, or possibly several times, by earthquake? The archeologists of the future may find several buried cities on the present site of San Francisco, if man insists on living at that point as the Pacific coast littoral becomes broader, and the Sierras rise higher to the accompaniment of unnumbered quakings and tremblings.

But even though stone, the favorite building material since prehistoric times, is able to survive or be spared the effects of earthquake, fire, vulcanism and flood, it is still subject to final and complete disintegration through the slow but continued action of the weather. Wind, rain, frost, the gases of the air, and even the humblest living organisms combine to overthrow that which man has erected, and which may have withstood all other destructive agents. In this respect granite is almost as unstable as the other varieties of building stones mentioned. The coarser the grains in a granite rock, the more easily the rock crumbles. It is readily split or fractured by frost, by trees, and even by the heat of the sun. Limestones and marbles are slowly dissolved by the carbon dioxide in rain and in percolating waters. If in contact with soils and vegetation, a similar effect is observed, due to the same cause. Sandstones may resist the effect of frost, rain, and carbon dioxide, but succumb at once to the chiseling effect of sand particles driven by the wind. Running water is often more active than wind, rain or air in disintegrating and pulverizing rocks; while a glacier either moves bodily whatever comes in its path, or rides over it and crushes it to the finest powder. After reviewing thus the effects of the principal destructive agents upon stone, to put our faith in stone as the sole protection to our treasures of the past and present would seem to be open to several objections.

Next to stone, we find man has discovered and placed a value upon certain substances which he has learned to call metals. At the present time we may be said to be living in the age of steel. Iron is our most important metal as it is the most useful and most abundant, or rather, is the cheapest and is most readily obtained in large quantities. Yet iron is the most perishable of all metals. Rust is the chief enemy of

all our iron and steel objects. To avoid rust has been the aim of man ever since he discovered iron and its uses. When quite pure, the rusting of iron is greatly retarded, but it is scarcely possible to indefinitely defend even pure iron against rust. Fire, sea-water, and ice, as well as the weather, could destroy a structure of iron in the course of time, and even in much less time than it would take the same agents to destroy a structure of stone. When properly imbedded in concrete, however, iron or steel not only adds greatly to the strength of the concrete, but is very much less liable to rust, owing to the protective effect of the cement.

If iron is of doubtful permanence, will other metals or alloys serve better? Undoubtedly some of them might, to a certain degree. Bronze is surely very resistant to the weather, as are its components, copper and tin. These, however, could be readily melted in a fire, as could zinc, aluminum and lead. Gold and silver are even more resistant to corrosion and high temperatures, but their cost prevents their extensive use. The same is true of platinum, tungsten, vanadium and still rarer metals. We can scarcely choose a single metal that will serve as an ideally resistant agent or material and at the same time be of practical use.

Clay products often appeal to us as having singular powers of resistance to certain destructive agents, but in all cases such products are found to have some fatal weakness. While quite resistant to the weather, and to a certain degree of heat, yet severe weather conditions or intense heat may destroy them. In most cases the practicable forms of these products are brittle, and for that reason are readily damaged. Ancient inscriptions in clay have been preserved for a very long time, and are of great interest and importance in archeology, but we should remember that the destructive agents directed against them did not include severe weather conditions nor high temperatures.

Possibly the most resistant mineral substances that appeal to modern man are asbestos and its allied minerals, talc, steatite and serpentine. These lend themselves readily to the shaping of numerous articles. Asbestos in particular is very familiar to us in its uses as a fire-proofing material and non-conductor of heat. Softness and brittleness, however, are objectionable properties of most products from these minerals, just as brittleness is a characteristic weakness of kaolinite or clay products.

Glass, while hard and resistant to the weather, is too readily injured by high temperatures, and is too brittle to give us much hope in our search for an ideally resistant material. While glass is of enormous importance in our modern civilization, it seems probable that most of it will remain in its present forms only under quite favorable conditions.

If the substances so far discussed are unsuitable for the purpose of perpetuating or safeguarding our records and relics of ancient and

modern times, the natural query is, "In what way or ways may we preserve the present for the future?" Most of our historical, scientific, religious, social, political and other kinds of documents are composed of flimsy and combustible materials, on which it is easy to almost completely and permanently obliterate or efface the written or printed record. The bulk of our modern paper is less permanent than that made two and three hundred years ago, or even the papyrus of the ancients. Yet we entrust our most precious records to the surface of a substance that can not be expected to endure two thousand years under the most favorable conditions. Photographs might be better preserved in the form of the original glass plate, or a non-combustible film, or best of all, as a half-tone or similar metallic engraving. The photographic print, or the print from an engraving is certainly as perishable as the paper on which it is made. History, art, literature, science, and written knowledge as a whole, may be transmitted to posterity in the form of copies, if necessary, using the proper measures to ensure authenticity as well as safety in preserving and protecting such copies until they are to be recopied or rewritten. But what of the originals of many historic documents, photographs, and the like? Will not these relics be of greater interest and value if they, and not mere copies, are preserved for the future? Copies of certain things, particularly works of art, are not always desirable, nor can these things always be copied to the best advantage. We may admire and cherish beautiful and costly mural paintings and other decorations, but can we be certain that the buildings containing them will escape complete destruction? The beautiful Library of Congress could be hopelessly ruined by a few well-directed bombs from a fleet of hostile airships, if not by the shells from some long range naval gun. Could its art treasures, not to speak of other kinds, be successfully restored? What would happen to the National Museum, and the museums, libraries, and art galleries of our coast cities in case of war and sudden attack? Have we any adequate or efficient means of preserving the products of man's genius and inventive skill? What machines could withstand the destructive agents cited? Do these questions concern us, or do they not?

Several years ago Mr. Percival Lowell wrote as follows:[1]

> One reflection well worth our thought the pyramids suggest: the enduring character of the past beside the ephemeralness of our day. We build for the moment; they built monumentally. True we have printing which they had not. But libraries are not lasting. Fire, accidental or purposive, has destroyed the greater part of the learning of the far past and promises to do so with what we write now; and what escapes the fire mold may claim. Only that idea which is materially most effectively clothed can withstand for long the gnawing disin-

[1] *Popular Science Monthly*, Vol. 80, p. 460 (1912).

tegration of time. The astronomic thought of the pyramid-builders lives on to-day; where will record of ours be, I wonder, five thousand years hence. We may be quoted indeed with ever-increasing inaccuracy of description. . . .

What answer can we make to this? Our nation has endured and prospered for one hundred and forty years. There are reasons for supposing that it will endure for another century, or two or three or ten centuries. But nature will not be idle all this time. She moves slowly, it may be, but nevertheless most surely. Is there not something that we, who are living here and now, can do to add to the good name which we all sincerely wish, as the United States of America, to leave to posterity?

We are greatly concerned in the topic of preparedness, for war or for peace, according to the way in which we recognize our individual duties and interpret our national needs. Is it wholly out of place to suggest that we also prepare for the contest which the objects we have fashioned and which we have held to be worthy must make with Mother Nature? Why should we stop at one thousand or five thousand years as the limit of our responsibility? What of us and our descendants ten—twenty—fifty—one hundred thousand years from now? If man is still man, will he not then have as great an interest in his antiquities as we have in ours? Knowing the conditions with which our present students of archeology have to contend, are we to take no thought of the possible problems of the future? The ancient monarchs who ruled flourishing empires thousands of years before our time have in many cases done us an inestimable service in causing their names and deeds to be inscribed in the most durable form known to their art. Are we to make no use of our superior knowledge in preserving for the future, not only our collections of antiquities, but an adequate record of our own national progress and current thought?

If it may be assumed that there is a modicum of agreement on the proposition of preserving the present for the future, we may naturally begin to inquire, what is to be done, and how shall it be done? The first question raises another of much greater scope, namely, what shall be selected, in case a move is made to preserve definite things for the benefit of future antiquarians? Possibly this question could best be settled by a commission, appointed by and under the direction of the federal government, sufficiently large and representative to bring forth all sorts of views on the problem. The work of such a commission would doubtless include discussions, decisions, and investigations concerning the worth and claims of the thousands of things that would be suggested on every hand. It is true that thousands of corner-stones of public buildings all over the country contain a record of a certain kind. But how adequate would such records be? We have in the corner-stone custom a primitive attempt at leaving some sort of record for the

future, in which we are outdone many times over by the customs of the ancient dwellers of Egypt and Babylon. We may have Halls of Fame, and galleries of statues, but they are necessarily somewhat too exclusive and intangible to satisfy the desires of the archeologists of the future. We might emulate the enterprise shown abroad in preserving phonograph records of living orators, singers, and instrumentalists. But why stop there? Our modes of recording history and noteworthy events seem to be at the height of perfection, and the preservation of photographs, moving-picture films, as well as the voices of our leading national figures is to add to the future an untold wealth of interest in us and what we have done, together with a better understanding. The selection, then, of that which we ought to make an especial effort to preserve would probably be based upon the relation of the objects and records to the history, progress, culture and life of the nation as a whole. That the project should be financed and carried out by the federal government will probably be agreed to by all.

As a secondary function of our hypothetical commission there remains the necessity of determining how we shall go about it to preserve these things, once they have been chosen. Our review of destructive agents, noting what they have done and still may do, as well as the consideration of the amount of resistance to these agents possessed by our present materials, causes us to confront the problem with some degree of anxiety, since no one of the materials known to man will serve for all the requirements of the problem's solution. This phase of the movement would likewise need careful thought and discussion, and it would probably be found that only a combination of materials would satisfy the requirements.

To paraphrase a well-known quotation, we can not predict in what century the "New Zealander will gaze on the ruins of Brooklyn Bridge." Nor can we say at what moment the hand of the invader will be stretched out to destroy or snatch away our treasures. It is true that in time of war, or under threat of ruin by fire, earthquake, glacier or volcano, we could remove a portion of our works of art, our relics of state, and our rarest collections to some safer quarter of the country. But would such a move be final or satisfactory? When the Washington monument and Grant's tomb are but rocky ruins in a watery waste, what will have become of the lesser works of the nation that erected these tributes to the memory of two of their most illustrious men? Let us determine that what we do leave shall be as well preserved as the remains of the trilobites of fifty million years ago, and that our mode of preservation shall contain less of accident and more of thoughtful design. Looking forward, can we see this as a portion of our duty to the future? If we can, let us set about the fulfilment of our duty, as becomes true Americans.

THE FAVORITE NUMBER OF THE ZUÑI

By ELSIE CLEWS PARSONS

LENOX, MASS.

IN the briefest acquaintance with Zuñi custom and tradition one is struck by the prominence of the numeral four, by its in fact obsessive character. It was on the first day of a recent visit to Zuñi I began to notice it. I had happened on the last of the summer so-called rain dances—the *kokokshi*. In the forelocks of the male figures in the dance were *four* yellow feathers, the bead work on the heel band of their moccasins represented the *four*-armed cross, their dance had to be repeated *four* times, I was told, in *four* plazas of the pueblo. Accompanying the dance or, so to speak, during its interstices, the *koyemshi* fooled about, and those antic figures the Americans call "Mudheads" numbered ten; but in their formal exit from the sacred plaza the *koyemshi* marching two by two divided into two slightly spaced sets, *four* in the first, six in the second. As I learned later, six and ten also play special rôles in Zuñi numeration, but they are, it is fair to say, quite minor rôles. As for eight and twelve, they figure too, but they figure as multiples of four.[1]

It would be tedious, if not impossible, to review the rôle of *four* in all the vast range of Zuñi ceremonial or mythology.[2] Let me give but a cross section of it, as it were, as it appeared to me in connection with the special subjects I was engaged in studying—the crisis ceremonial of Zuñi life, Zuñi beliefs and practises in connection with birth and growth and death.

I begin, remote as it may seem, with a rabbit hunt. But the *quadrennial* sacred rabbit hunt, the hunt with the *koko* or gods, is in an important part a phallic rite. Upon its proper performance and the correct stage-managing of the Chakwena, the Rabbit Huntress, depend the plentifulness of rabbits and of humans. *Four* days before

1 For example, formerly after killing a Navaho all members of the expedition party were "sacred," *i. e.*, called upon to plant prayer plumes and precluded from sexual intercourse *four* days, but the actual slayer was sacred eight days, *four* days for the slain man, *four* days for himself, and the priest of the Bow was sacred twelve days, *four* days for the slain, *four* for A'hajuta, the elder war god, and *four* for himself.

2 I may refer *passim* to Cushing, F. H., "Zuñi Creation Myths," XIII. (1891–2), *Ann. Rep. Bur. Amer. Ethnol.*; *Ib.*, "Zuñi Folk Tales," New York, 1901; Stevenson, M. C., "The Zuñi Indians," XXIII. (1901–2), *Ann. Rep. Bur. Amer. Ethn.* For the prominence of the same numeral among the Hopi, see Fewkes, J. W., "The Ceremonial Circuit among the Village Indians," *J. Amer. Folk-Lore*, V. (1892), 39–41.

the time set for the hunt a single rabbit is killed and its blood smeared on the legs of the Chakwena—to be rubbed off in the hunt against the plants she brushes through. For failure to catch a rabbit in the chase, *four* times a man or a "god" is struck, once on each arm and each leg. *Four* times the rabbits are run out from the surrounded areas, *four* times before the hunt turns into a secular and comparatively individualistic activity.

The hunt over, the Chakwena retires to one of the *kewitsine* or sacred club-houses,[3] where for *four* days she lies in on a warmed-up sand-bed as would a woman in her confinement, and where she is taken care of by the woman who expects by this rite of imitative magic to conceive the offspring she desires. At the close of the fourth day the would-be mother receives from the Chakwena the two ears of corn she has carried in the hunt and gives in turn to the Chakwena two other ears—*four* ears of corn figuring in that give and take.

There are other ways to promote conception, but in this connection I need refer only to the conception of twins or rather to the means taken to inhibit it. The woman who eats of the wafer bread her husband brings back with him from his deer hunt will bear twins—since the deer have twins—unless the bread is passed around the rung of her house ladder *four* times.[4]

In a real confinement the period set for it is, as in the case of the mock confinement of the Chakwena, *four* days,[5] or it may be eight days or ten or twelve—whatever the familial practise—and (this is a fact of great interest, I think) any departure from the set practise means that the mother will "dry up," get thin and die.

Were a hemorrhage to set in through the cord of the infant, it is

[3] There are *six* of them, one devoted to each of the *six* directions, north, south, east, west, the zenith and the nadir. That inspiring student of Zuñi, Frank H. Cushing, added to these directions a seventh, the middle, and seven, he stated, was a sacred number to the Zuñi. (Fewkes, p. 39, n. 2. See too Cushing, "Zuñi Creation Myths," p. 373.)

[4] *Four* figures in other connections in deer hunting. The night before the hunt eight prayer plume bundles are prepared, four for the *koko,* four for the deer.

[5] The Hopi confinement lasts four days. On the twentieth day, the day of the purifying and naming ceremonial, the "godmother" marks the house walls and floor with *four* parallel lines of meal. *Four* times she touches the head of the mother with an ear of corn dipped each time into yucca suds. The bowl in which the head is washed is thrown off the mesa after it has been waved over the spot of the lustration *four* times. In the corresponding Tewan ceremony after the mother presents the infant to the sun she turns around on the spot *four* times. (Owens, J. G., "Natal Ceremonies of the Hopi Indians," pp. 168–9, 170, 174. *J. Amer. Ethnol. and Archeology,* II. (1892).) Four days was the confinement period of the Nahuas of Mexico, the numeral being prominent in much of their ceremonialism. (Brinton, D. G., "The Myths of the New World," p. 90. New York, 1896.)

supposed that some one has been in the room who has been bitten by a dog or a snake. He would have to be found and then to save the life of the child he would have to wave some ashes over the heads of both child and mother—waving them *four* times.

Birthdays are not observed in Zuñi, but a kind of grouping by age there seems to be, for every *four* years an initiation into the *kotikili* is held and boys become eligible for this initiation some time after their first four-years age period, apparently towards the close of their second, *i. e.,* they are not initiated before they are four and they may be initiated before they are eight. In the initiation ceremonial *four* is very prominent. The ceremonial lasts *four* days, days in which the initiate fasts from meat. As he passes between the lines of the twelve *salimobi'ya,* he is whipped[6] by each masked figure *four* times.

But even before the initiation the development of Zuñi children, and, in this case, of girls,[7] as well as boys, is attended to, ceremonially. During the *watempla* dances, purificatory dances of late winter and early spring, the masks known as the *adoshlĕ* and the *suukĕ* pay domiciliary visits upon refractory children. Into the disciplinary effect of these terrifying personages we need not go, noting only that *four* times they have to advance upon a house before its adult inmates stop beating upon their pans and drums to pretend to scare them away.

Into Zuñi marriage practises *i. e.,* into a first marriage I have found no numeral obtrusion, but here my observations are by no means final. In the marriage of the widowed the favorite number does occur. Early in the morning after the couple has first slept together the second spouse gives to the remarried one something of value. This object with something belonging to himself or herself the remarried throws in the roadway. Whoever would pick these things up and appropriate them must first kick them *four* times with the left foot and then wave over the things a bit of cedar bark held in the left hand, waving it *four* times. Meanwhile the wedded pair must cut and plant their prayer plumes and stay continent,[8] *four* days for the deceased, and again cutting and planting the plumes, *four* days for themselves.

Immediately after the death of a spouse, the widowed has also planted plumes, again *four* days for the deceased and *four* days for himself or herself. *Four* days it takes the deceased to reach *kothlu-*

[6] Whipping *four* times figures in the restoration of one who has had a bad dream.

[7] Girls are seldom initiated into the *kotikili.* There are in it now *four* women and there were in it in 1902, Mrs. Stevenson reports, *four,* but the occurrence of that ubiquitous number is, in this case, I have been told, a mere fortuity.

[8] *Four* days before every plume planting and *four* days afterwards continence is required. The initiated, *i. e.,* all the men and some of the women, plant plumes every moon and on many other ceremonial occasions.

wala,[9] where live below the Sacred Lake the dead.[10] And during these *four* days the house door is left ajar, the mourners may not buy or sell, and the bowl the hair of the dead has been washed in and the implements used in digging the grave all are left out on the house top.

In the cult of the dead *four* also figures. Formerly warriors and still to-day foot racers visit the bank of the river the night before their enterprise to plant plumes in honor of the dead and to bury wafer bread. Prayer and offering made, they move back *four* steps, then sit and listen. *Four* times they thus step backwards and sit and listen.[11]

Mourning usage is ever a very conservative usage, perhaps the most unchanging of all social practises, and so I infer from the prevalence of four in it as well as from its prevalence in all the Zuñi sacerdotal rites and traditions, beds of conservatism too, that the possession of the Zuñi mind by their favorite numeral is very, very ancient.[12] Is it obsolete? I may be asked. A truly satisfactory answer would require prolonged observation. I have noted a few facts however, which suggest at least that the rule of the favorite number is not yet merely historic.

In certain accounts given a well-known ethnographer of Zuñi, accounts reliable Zuñi tell me are erroneous, the numeral four figures quite as prominently as in the unquestioned traditions or practises, *i. e.*, in freshly "made up" stories *four* still figures.[13] I too collected a tradition that shows on its face a comparatively recent origin, a tradition of tribal origins. First to come up into the world, I was told, were the Pimas, the Navaho, the Moki and the peoples of other pueblos, then came the Mexicans, then the "Americans," *fourthly* the Ashiwi or Zuñi.[14] Again in the Zuñi sheep brand, a comparatively late *in-*

[9] The death trip takes this time among many American tribes. (Brinton, p. 90.)

[10] Zuñi who have represented the *koko* live after death in a hill-side, in a *four*-roomed dwelling. To the Sacred Lake southwest of Zuñi a *quadrennial* ceremonial journey is made.

[11] If they hear sounds of the river roaring or of an owl hooting or of lips smacking or of horse hoofs, it is well. To hear nothing is not well.

[12] Its prominence among the other pueblos would indicate too that it had asserted itself in the matrix pueblo culture, if not, given its prominence likewise in many American tribes, in a still more ancient culture.

[13] An infant's skin is rubbed with ashes to depilitate it but no trace of evidence of belief that exfoliation occurs within *four* days could I find. Cp. Stevenson, "The Zuñi Indians," p. 300 n. b. The statement that the forbidden sight of the Sacred Lake will cause visions and death I verified, but the further statement that the death would result in four days (see *Ib.*, p. 356)—this statement was denied. Nor is it believed that the dead live in a house in *kothluwala* containing *four* windows. It were tiresome to continue this list.

[14] This fourth emergence from the Sacred Lake, let me note incidentally, greatly pleased the Sun, because now at least on earth were some to talk his language.

vention, I'm justified in seeing, I think, the use or influence of four. Again, twice during the lifetime of my elderly informant has a Priest of the Bow attempted to establish an innovation[15] in pottery making, relegating and limiting its making to the ceremonial *four* days of the summer solstice,[16] the firing of all the ware to take place on the *fourth* day.

But one striking modern breakdown in the rule of four I did find. The governor of Zuñi, the lieutenant governor and the members of their staffs, their *tenientes* as they are called, no longer make up a board of eight. The three *tenientes* under the governor have been increased first to four then to five, the three under the lieutenant-governor, to four, increases the *practical* needs of government have in recent years required.[17] But the procedure of the board continues, let me add, unchanged. Adjudications are not made by the governor until each *teniente* has in turn made his suggestions and each makes them *four* times.

In conclusion let me give the answers I got when I asked, "Why four?" The first was given me by a Rain priest. "Because," he said, "when the people came up into the world at *kothluwala* they stayed there *four* time periods and as they moved about later they always stayed *four* time periods in each place." The explanation called to mind that offered by another people of early culture for their own sacred number, the number seven. The second answer to my query was given me by a medicine-man of the *Ne'wekwe* Fraternity. "Why four? Because," he said, "the Americans do not always speak the truth. They will give any number. But the Zuñi speak the truth and so they give the true number, the number *four*." Would it not be difficult to get a better illustration of how number may indicate subjective states of mind rather than objective circumstances?

15 Compare Stevenson, "The Zuñi Indians," p. 150. One of these periods must have occurred while Mrs. Stevenson lived in Zuñi. The custom my informant declared an innovation, an innovation lasting only while its sponsor, the Bow Priest, lived, may have been of course the revival by him of an ancient custom.

16 During these days none buys or sells or indulges in sexual intercourse. During the first *four* days of the winter solstice ceremonial members of fraternities and the *ashiwani* or rain priests and their households may not buy or sell or eat salt or meat or grease. For *ten* days none may carry out refuse of any kind from a house.

17 Of interest in this connection is the moot question whether or not these officials are Spanish made. They were—at the close of the seventeenth century—according to Cushing. ("Zuñi Creation Myths," p. 332.)

THE ORIGIN AND EVOLUTION OF LIFE ON THE EARTH

By HENRY FAIRFIELD OSBORN

COLUMBIA UNIVERSITY, AMERICAN MUSEUM OF NATURAL HISTORY

LECTURE II PART II

EVOLUTION OF THE FISHES

FOLLOWING the pro-fishes of Odrovician time (p. 508) the great group of fishes begins its evolution with (*A*) active, free-swimming, double pointed types of fusiform shape, adapted to rapid motion through the water and to predaceous habits in pursuit of swift-moving prey. From this type there radiated many others: (*B*) the deep, narrow-bodied fishes of relatively slow movements, frequenting the middle

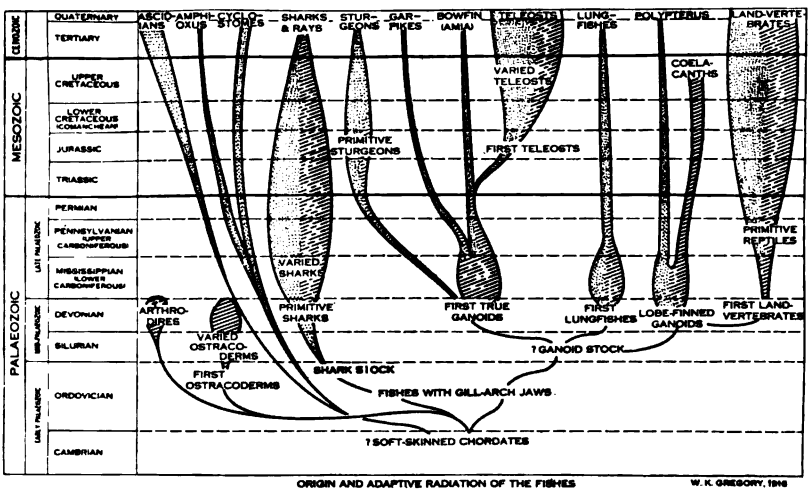


FIG. 9*a*. ORIGIN AND ADAPTIVE RADIATION OF THE FISHES SHOWING THE NOW EXTINCT SILURO-DEVONIAN GROUPS, the Ostracoderms and Arthrodires, in relation to the surviving lampreys (Cyclostomes), sharks, and rays (Elasmobranchs), sturgeons, garpikes, bowfins (Ganoids), bony fishes (Teleosts), primitive and recent lung-fishes (Dipnoi), and finally the fringe-finned Ganoids (Crossopterygii) from the cartilaginous fins of which the fore and hind limbs of the first land-living vertebrates (Tetrapoda) were derived. Dotted areas represent groups which still exist. Hatched areas represent extinct groups. Prepared for the author by Wm. K. Gregory.

depths of the waters; (*D*) the swift-moving, elongate types which increasingly depended upon lateral motions of the body for propulsion and thus tended to lose the lateral fins and finally to assume an elongate, eel shape entirely finless; (*C*) other bottom-living forms in which the body became laterally flattened, the head very large relatively and covered with protective dermal armature, the movements of the animals very slow.

Smith Woodward[6] has traced similar radiations of body form in the historic evolution of each of the great groups of fishes.

The importance of this law of form radiation is greatly enhanced

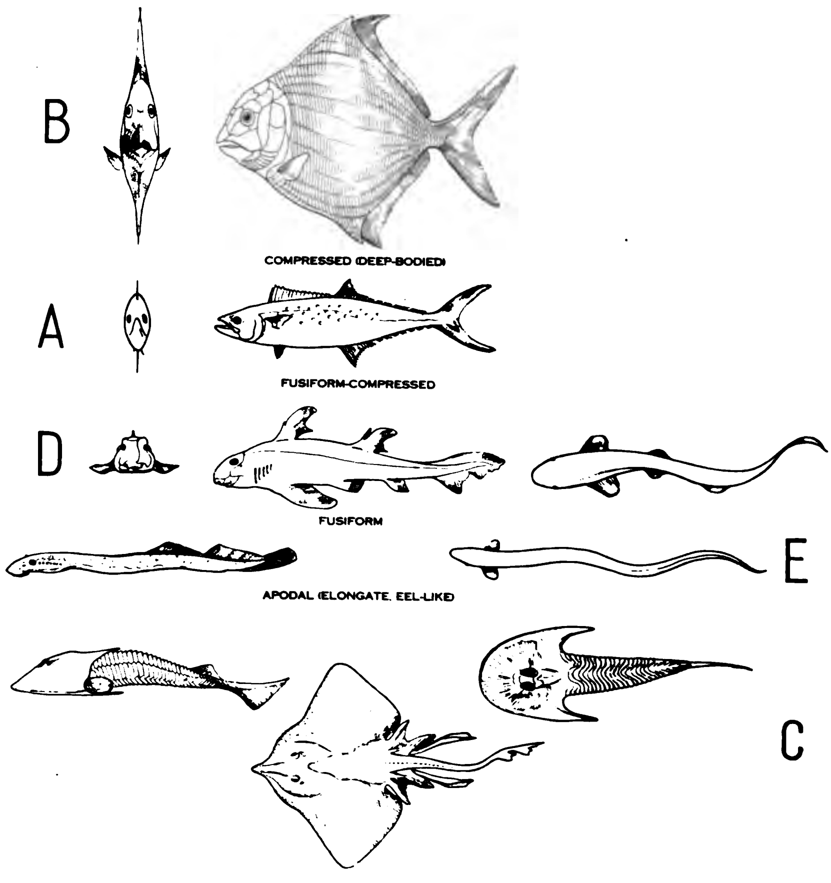


FIG. 9b. THE FIVE PRINCIPAL TYPES OF BODY FORM IN FISHES, beginning with (*A*) the swift-moving, compressed, fusiform types which pass, on the one hand, into (*B*) the compressed, slow-moving, deep-bodied types, and, on the other, into (*C*) laterally depressed, round, bottom-dwelling, slow-moving types, also into (*D*) elongate, swift-moving, fusiform types which grade into (*E*) the eel-like and swift-moving, bottom-living types without lateral fins. These five types of body form in fishes independently arise over and over again in the various groups of this Order. Partially parallel forms also appear among the Amphibia, Reptilia, and Mammalia. Prepared for the author by Wm. K. Gregory and Erwin S. Christman.

when we find it repeated successively among the aquatic Amphibia, Reptilia and Mammalia as one of the invariable effects of the *coordination of the mechanism of motion with that of offense and defense.*

[6] Smith Woodward, A., "The Use of Fossil Fishes in Stratigraphical Geology," *Proc. Geol. Soc. of London,* Vol. LXXI., Pt. 1, 1915, pp. lxii–lxxv.

In each of these four or five great radiations of form, from the swift-moving to the bottom- or ground-living, slow, armored types, there is usually an increase of bodily size, also an increase of specialization, the maximum in both being reached just before the period of extinction arrives.

FIG. 10. ARMORED, BOTTOM-LIVING OSTRACODERM TYPE, *Bothriolepis*, from the Upper Devonian of Canada, with chitinous armature and a pair of anterior appendages analogous to those in Eurypterids. This cluster of animals was undoubtedly buried simultaneously while headed against the current either in search for food or for purposes of respiration. After Patten, *op. cit.*

The Ordovician Ostracoderms are very little known. The Upper Silurian Ostracoderms enjoyed a wide distribution in Europe and America. They include both the fusiform free-swimming type (*Birkenia*) and the depressed ray-like types (*Lanarkia*, etc.). They apparently had not yet acquired cartilaginous lower jaws and appear to be in a lower stage of evolution than the true fishes. The armature is arranged in shield and plate form in *Palæaspis*, from the Upper Silurian Salina time of Schuchert, where we obtain our first glimpse of North American land life in the presence of the oldest known air-breathing animals, the scorpion spiders, and also the first known land plants. There are many indications of an arid climate. In Upper Silurian

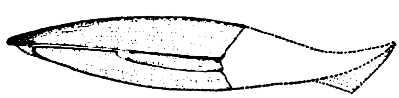


FIG. 11. THE *Palæaspis* OF CLAYPOLE AS RESTORED BY DEAN.

time the Ostracoderms reach the slow, armored, bottom-living stage of evolution, as typified in the Pteraspidians and Cephalaspidians, which were widely distributed in Europe, in America, and possibly in the Antarctic regions, as indicated by recent explorations there. Belonging to a *very distinct order* or subclass (Antiarchi) are certain armored Devonian forms (*Bothriolepis, Pterichthys*, etc.), which possessed a pair of jointed lateral appendages. Propelled by a pair of appendages attached to the anterior portion of the body; some of these animals (*Bothriolepis*) present analogies to the eurypterids (Merostomata, or Arachnida).

In the freshwaters of the Lower Devonian have been discovered the

ancestors of the heavily armored fishes known as the **Arthrodira,** a group of uncertain relationships. They have many characters in common with *Bothriolepis* (joint-neck, dermal jaws, carapace and plastron, paired appendages (*Acanthaspis*)). Dean, Hussakof and others regard the balance in favor of relationship with the stem of the Antiarchi (*Bothriolepis*). In the Middle Devonian (the Cleveland shales of Ohio) they attain the formidable size shown in the species *Dinichthys intermedius*. Like the Ostracoderms these animals are not central or in the main lines of fish evolution but represent collateral lines which early attained a very high degree of specialization followed by extinction.

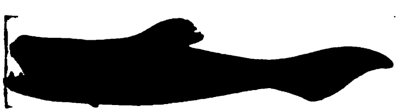


FIG. 12. RESTORATION OF THE GIGANTIC MIDDLE DEVONIAN ARTHRODIRAN (JOINTED NECK) FISH *Dinichthys intermedius*, EIGHT FEET IN LENGTH, OF THE CLEVELAND SHALES (OHIO), showing the bony teeth and bony armature of the head region. Lateral view of the same model in the American Museum of Natural History. Model by Dr. Louis Hussakof and Mr. Horter.

The central line of fish evolution is found in the typical cartilaginous skeleton and jaws and four fins of the primordial sharks, the primitive fusiform stage of which appears in the spine-finned type (Acanthodian) of Upper Silurian time. The relatively large-headed, bottom-living types of sharks do not appear until the Devonian, during which epoch the early swift-moving, fusiform predaceous types branch off into the elongated eel-shaped forms of the Carboniferous. The prototype of the shark group is the *Cladoselache*, a fish famed in the annals of comparative anatomy since it demonstrates that the fins of fishes arise from lateral skin folds of the body with internal stiffening cartilaginous rods (Fig. 13), which in course of evolution are concentrated to form the central axis of a freely jointed fin, while in a further step of evolution they transform into the cartilages and bones of the limb girdles and limb segments of the four-footed land vertebrates (Tetra-

poda). The manner of this transformation has been one of the greatest problems in the solution of the origin of animal form since the earliest researches of Carl Gegenbaur of Heidelberg, who sought to derive the lateral fins from modification of the cartilaginous rods supporting the gills, through a profound change of function. While paleontology has disproved Gegenbaur's hypothesis that the limbs of the higher vertebrates, including those of man, are derived from the gill arches of fishes, it has helped to demonstrate the truth of Reichert's hypothesis that the bony chain of the middle ear of man has been derived through change of function from a portion of a modified gill arch (mandibular cartilage) of the fish.

The cycle of shark evolution in course of geologic time embraces a majority of the swift-moving, predaceous types, which branch into the sinuous, elongate body of the frilled shark (*Chlamydoselache*) and into forms with broadly depressed bodies such as the bottom-living skates and rays. Under the law of adaptive radiation the sharks seek every possible habitat zone in the search for food. The nearest approach to the eel-shaped type among the sharks are certain forms discovered in Carboniferous time. By Upper Devonian time the fishes in general had already radiated into all the great existing groups. The primitive armored Arthrodires and Ostracoderms were nearing extinction. The sharks were still in the early lappet-fin stage of evolution above described, a common characteristic of the family being that they never evolved a bony armature. The scaled armature of the first true Ganoid fishes (*Osteolepis, Cheirolepis*) makes its first appearance. These armored knights of the sea are related to simpler forms which gave rise to the rich stock of sturgeons, garpikes, bow-fins, and true bony fishes (Teleosts) which now dominate all other fish groups both in the fresh-waters and the seas. Close to this stock are the first lung fishes (Dipnoi), represented by *Dipterus*; also the "lobe-" or "fringe-finned" Ganoids from which the first land vertebrates were derived. From a single locality, in the Old Red Sandstone of Scotland, Traquair has

FIG. 13. (UPPER.) *Cladoselache*, THE TYPE OF THE PRIMITIVE DEVONIAN SHARK OF OHIO WITH PAIRED AND MEDIAN FINS PROVIDED WITH ROD-LIKE CARTILAGINOUS SUPPORTS, from which type by fusion the limbs of all the higher land vertebrates have been derived. Model by Dean, Hussakof and Horter from specimens in the American Museum of Natural History.

(LOWER.) THE LAPPET FINS OF *Cladoselache* SHOWING THE CARTILAGINOUS RAYS (WHITE) WITHIN THE FIN (BLACK). After Dean.

recovered a whole series of these archaic fish types as tl in the fresh water or the brackish pools of Upper Devoı 14.)

In this period the paleogeographers (Schuchert) evidence of the evolution of the terrestrial environme

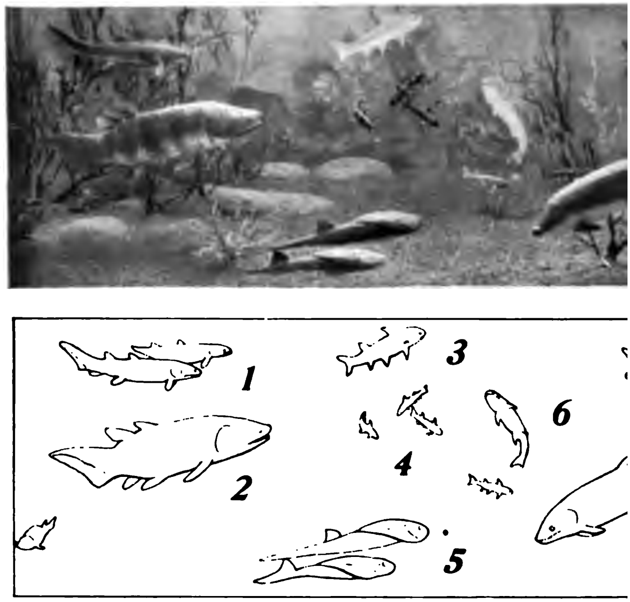


FIG. 14. FISH TYPES OF THE OLD RED SANDSTONE OF SCOTI IAN TIME. PRIMITIVE GANOIDS (*Osteolepis*, *Cheirolepis*), primitiv Acanthodians (*Diplacanthus*), bottom-living Ostracoderms (*Pterichi* (*Dipterus*), partly armored Ganoids (*Holoptychius*). 1, *Osteolepis*, Ganoid. 2, *Holoptychius*, fringe-finned Ganoid. 3, 6, *Cheiracanth* (Acanthodian). 4, *Diplacanthus*, spine-finned shark (Acanthod primitive Arthrodiran. 7, *Cheirolepis*, primitive Ganoid. 8, 9, lung fish. 10, *Pterichthys*, bottom-living Ostracoderm allied to in the American Museum of Natural History, restorations by Horter, partly after Traquair.

tions of the existence of parallel mountain ranges on of active volcanoes in the Gaspé region of New B mountain formations of South Africa, and in the d center of the Eurasiatic continent into the great centr sea, the *Tethys* of Suess. In the seas of this time a Cambrian seas we observe that the trilobites are in a the brachiopods are relatively less numerous, the echi resented by the bottom-living starfishes, the sharks are a throdiran fishes are still abundant in Germany.

It was long believed that the Amphibia evolved the air-breathing fishes of the inland fresh waters, an was stoutly maintained by Carl Gegenbaur, who uphel

the Archipterygian theory of the origin of the limb, seeking the prototype of the modern limbed forms in the fin of the modern Australian lung fish, *Ceratodus*. This hypothesis of Gegenbaur, warmly supported by a talented group of his students, is memorable as the last of the great hypotheses regarding vertebrate evolution founded exclusively

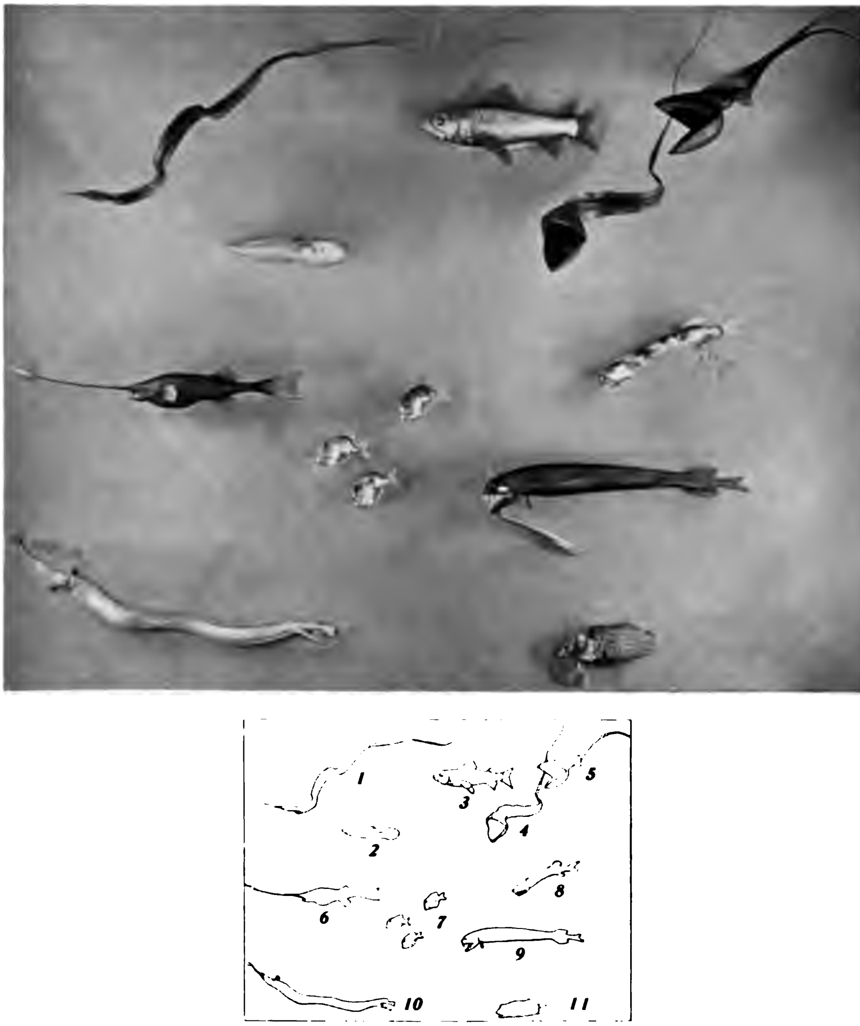


FIG. 15. THE EXTREMES OF ADAPTATION IN MOTION AND ILLUMINATION IN THE EXISTING BONY FISHES (TELEOSTS) OF THE ABYSSAL REGIONS OF THE OCEANS. Although many different orders of Teleosts are represented each type has acquired phosphorescent organs, affording a fine example of convergence. The body form is of great diversity.

1, Thread-eel, *Nemichthys scolopaceus* Richardson. 2, *Barathronus diaphanus* Brauer. 3, *Neoscopelus macrolepidotus* Johnson. 4, 5, *Gastrostomus bairdi* Gill and Ryder. 6, *Gigantactis vanhoeffeni* Brauer. 7, *Sternoptyx diaphana* Lowe. 8, *Gigantura chuni* Brauer. 9, *Melanostomias melanops* Brauer. 10, *Stylophthalmus paradoxus* Brauer. 11, *Opisthoproctus soleatus* Vaillant.

upon comparative anatomy and embryology as opposed to the triple evidence afforded by these sciences when reenforced by paleontology.

It is through the discovery of primitive types of the fringe-finned ganoids, to which Huxley gave the appropriate name Crossopterygia, that the true ancestry of the Amphibia and of the amphibian limb has

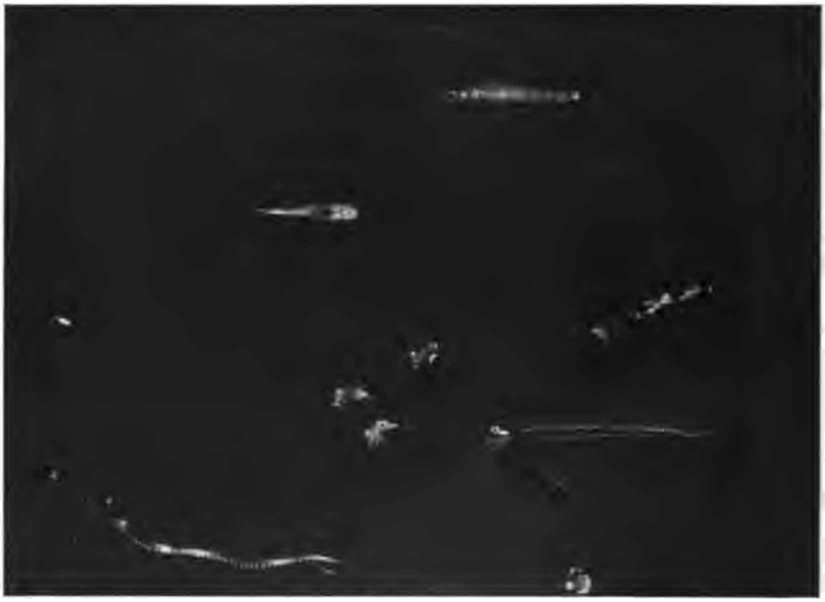


FIG. 16. PHOSPHORESCENT ILLUMINATING ORGANS OF THE ABYSSAL FISHES REPRESENTED IN FIG. 15, as they are supposed to appear in the darkness. After models in the American Museum of Natural History.

been traced, as due to a partial change of function whereby the propelling fin was gradually transformed into the propelling limb. This implies a long terrestrio-aquatic phase in which the fin was partly used for propulsion on muddy surfaces (Fig. 17). In the parallel retrogressive evolution of the lung fishes (*Lepidosiren, Gymnotus*) the fringe-finned fishes (*Calamoichthys*) and the bony fishes (*Anguilla*) the final eel-shaped, finless stage is either approached or actually passed.

The bony fishes (Teleosts), which first emerge as a distinct group in Jurassic time, radiate adaptively into all the great body types attained by the older groups, more or less closely imitating each in turn, so that it is not easy to distinguish superficially between the armored catfishes (*Loricaria*) of the existing South American waters and their prototypes (*Cephalaspis*) of the early Paleozoic. The most extreme specialization in this great group is to be found in the radiations of abyssal fishes into slow- and swift-moving forms inhabiting the great depths of the ocean, adapted to tons of water pressure, to temperatures

just above the freezing point, and to total absence of light which is compensated for by the evolution of a great variety of phosphorescent light producing organs.[7] Another extreme of chemical evolution among

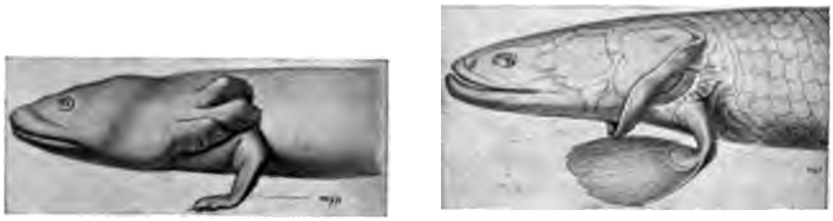


FIG. 17. THEORETIC MODE OF CONVERSION OF THE LOBE-FIN OF THE FISH (RIGHT) INTO THE FOOT OF AN AMPHIBIAN (LEFT) through loss of the dermal fringe border and rearrangement of the cartilaginous supports of the lobe. After Klaatsch.

the fishes is the production of electricity as a protective function, which is even more effective than bony armature because not interfering with rapid motion. In only a few of the fishes is electricity generated in sufficient amounts to thoroughly protect the organism. It develops through modified body tissues in the form of superimposed plates

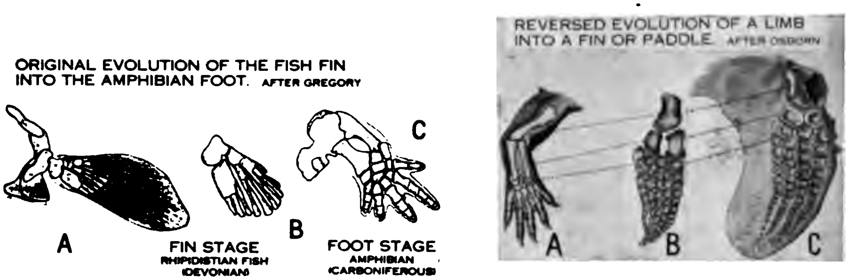


FIG. 18. (LEFT.) DIRECT ORIGINAL EVOLUTION OF THE BONES OF THE LOBE-FIN OF A FISH (*A, B*) (*Rhipidistia* type of Cope) into the bony, five-rayed limb (*C*) of the Amphibian of the Carboniferous age.

(RIGHT.) SECONDARY REVERSED EVOLUTION OF THE FIVE-RAYED LIMB OF A LAND REPTILE (*A*) into the fin, or paddle (*B, C*) of an ichthyosaur.

(electroplaxes) separated equally from one another by layers of a peculiar jelly-like connective tissue, all lying parallel to each other and at right angles to the direction of discharge. The electric organ is formed from modified muscle and connective tissue and is innervated by motor nerves. The physical principle involved is that of the concentration cell, and the electrolyte used in the process is probably sodium chloride. The theory is that at the moment of discharge a membrane is formed on one surface of the electroplax which prevents the negative ions from passing through while the positive ions do pass

[7] The author is especially indebted to Professor Ulric Dahlgren, of Princeton University, for notes upon phosphorescent and electric organs.

through and form the current. The strength of the current varies from four volts in *Mormyrus* up to as much as 250 or more in *Gymnotus,* the electric eel, and consists of a series of shocks discharged 3/1000 of a second apart.

EVOLUTION OF THE AMPHIBIA

A single impression of a three-toed footprint (*Thinopus antiquus*) in the Upper Devonian shales of Pennsylvania constitutes at present the sole paleontologic proof of the period of transition from the fish

FIG. 19. FOOTPRINT OF *Thinopus antiquus* MARSH, THE EARLIEST KNOWN LIMBED ANIMAL, an Amphibian from the Upper Devonian of Pennsylvania. Type in the Peabody Museum of Yale University. Photograph of cast presented to the American Museum by the Peabody Museum.

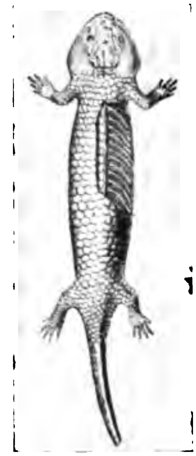


FIG. 20. THE TYPE OF SALAMANDER-LIKE PRIMITIVE AMPHIBIAN OF UPPER DEVONIAN TIME (*Pentadactyloidea, Tetrapoda*), with large, solidly roofed skull, four limbs, and five fingers on each of the fore and hind feet. After Fritsch.

type to the amphibian type. This took place in Lower Devonian if not in Upper Silurian time. The adaptive radiation of these primordial Amphibia probably began in Middle Devonian time and extended through the great swamp, coal-forming period of the Carboniferous, which afforded over vast areas of the earth's surface ideal conditions for amphibian evolution, the stages of which are best preserved in the Coal Measures of Scotland, Saxony, Bohemia, Ohio and Pennsylvania, and have been revealed through the studies of von Meyer, Owen, Fritsch, Cope, Credner and Moodie. The earliest of these terrestrio-aquatic

types have not only a dual breathing system of gills and lungs but a dual motor equipment of limbs and a propelling median fin in the tail region.

So far as known primordial Amphibia in body form were chiefly of the small-headed, long-bodied, small-limbed, tail-propelled type of the modern salamander and newt. The large-headed, short-bodied types (*Amphibamus, Pterophlax*) were primitive. In Upper Carboniferous and early Permian time the terrestrial forms began to be favored by the land elevation and recession of the sea which distinguished the close of the Carboniferous and early Permian time. Under these varied zonal

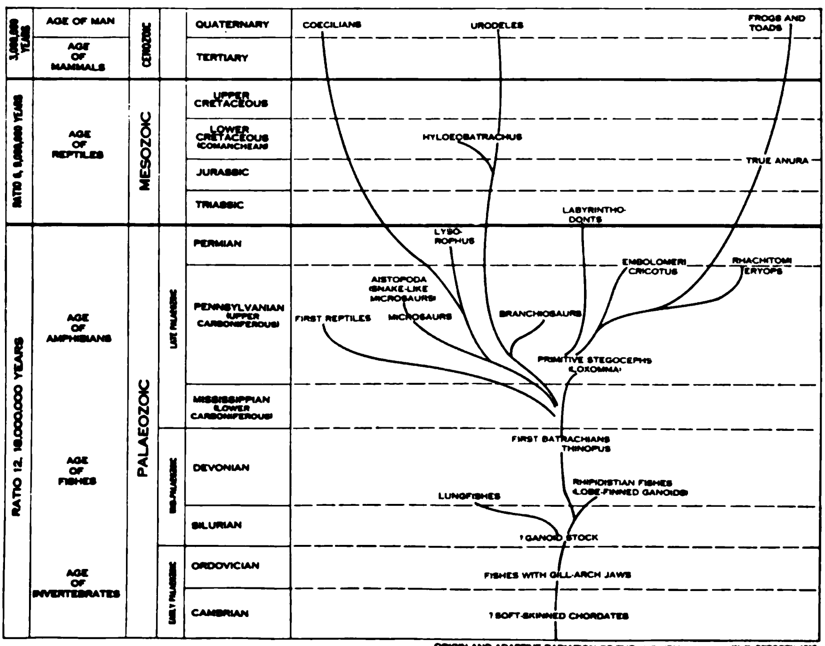


FIG. 21. DESCENT OF THE AMPHIBIA IN WHICH THE FIN IS TRANSFORMED INTO A LIMB (*Thinopus*), from an ancestral Ganoid fish stock of Silurian age through the fringe-finned Ganoids. From this group diverge the ancestors of the Reptilia and the salamander-like Amphibians which give rise to the various salamander types, also to branches of limbless and snake-like forms (*Aistopoda,* modern Cœcilians). The other great branch of the solid-skulled Amphibia, the Stegocephala, was widespread all over the northern continents in Permian and Triassic time (*Cricotus, Eryops*), and from this stock descended the modern frogs and toads (*Anura*). Prepared for the author by Wm. K. Gregory.

conditions, aquatic, palustral, terrestrio-aquatic, fossorial and terrestrial, the Amphibia radiated into several habitat zones and adaptive phases, thus recapitulating all the chief types of body form which had previously evolved among the fishes and anticipating many of the types of body form which were to evolve among the Reptilia. One ancestral feature is a layer of superficial body scales derived from those of their

fringe-finned fish ancestors; with the loss of these scales most of the Amphibia also lost the power of forming a bony dermal armature.

Recent researches in this country, chiefly by Williston and Case, indicate that the solid-headed Amphibia (Stegocephala) and primary forms of the Reptilia chiefly belong to late Carboniferous (Pennsylvania) and early Permian time. They are found abundantly in pool deposits widespread over the southwestern United States and Europe associated in rocks of a reddish color, which point to aridity of climate in the northern hemisphere during the period in which the terrestrial adaptive radiation of the Amphibia occurred. These arid conditions continued during the greater part of Permian time, especially in the northern hemisphere. In the southern hemisphere there is evidence even of a period of extensive glaciation, which was accompanied by the disappearance of the old lycopod flora (club mosses) and arrival of the cool fern flora (*Glossopteris*) which appeared simultaneously in South America, South Africa, Australia, Tasmania and southern India. The widespread distribution of this flora in the southern hemisphere furnishes one of the arguments for the existence of the great South Pacific continent *Gondwana,* a hypothesis of Suess which is supported by Schuchert. In North America Permian glaciation was only local. The last of the great Paleozoic seas disappeared from the surface of the continents, while the border seas give evidence of the rise of the ammonite cephalopods. Toward the close of Permian time the continent was completely drained. Along the eastern seaboard the Appalachian revolution occurred, and the mountains rose to heights estimated at from three to five miles.

FIG. 22. SKELETON OF *Eryops* FROM THE PERMO-CARBONIFEROUS OF TEXAS, type of the stegocephalian Amphibians which were structurally ancestral to the Labyrinthodonts of the Triassic. Mounted in the American Museum of Natural History.

Evidences of extensive continental connections in the northern hemisphere are found in the community of type between the great terrestrial amphibians of such widely separated areas as Texas and Württemberg which develop into similar resemblances between the great Labyrinthodont amphibians of Lower Triassic times of Europe, North America and Africa. Ancestral to these Triassic giants is the large, sluggish, water- and shore-living *Eryops* of the Texas Permian, with

massive head, depending on its short, powerful limbs and broad, spreading feet for land propulsion and in a less degree upon its tail for pro-

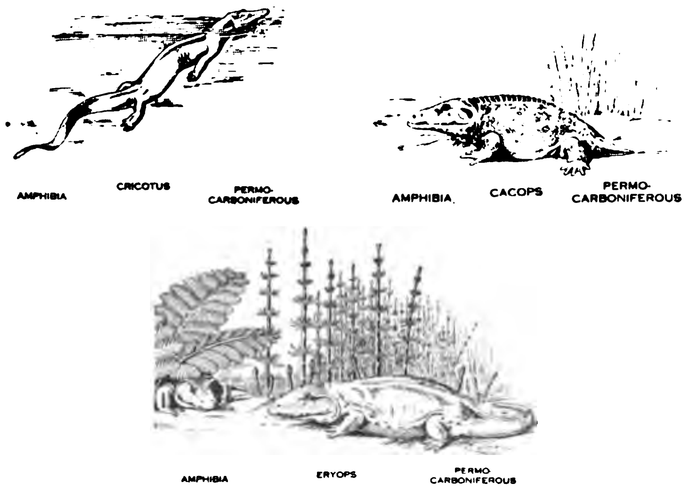


Fig. 23. Amphibia of the American Permo-Carboniferous, the free-swimming *Cricotus*, short-bodied *Cacops*, and continuation of the amphibious short-tailed terrestrial type, the large, solid-headed *Eryops*. Restorations for the author by Gregory and Deckert.

pulsion in the water. This form may be a collateral ancestor of the Labyrinthodonts; it belongs to a type which spread all over Europe and North America and persisted into the *Metopias* of the Triassic.

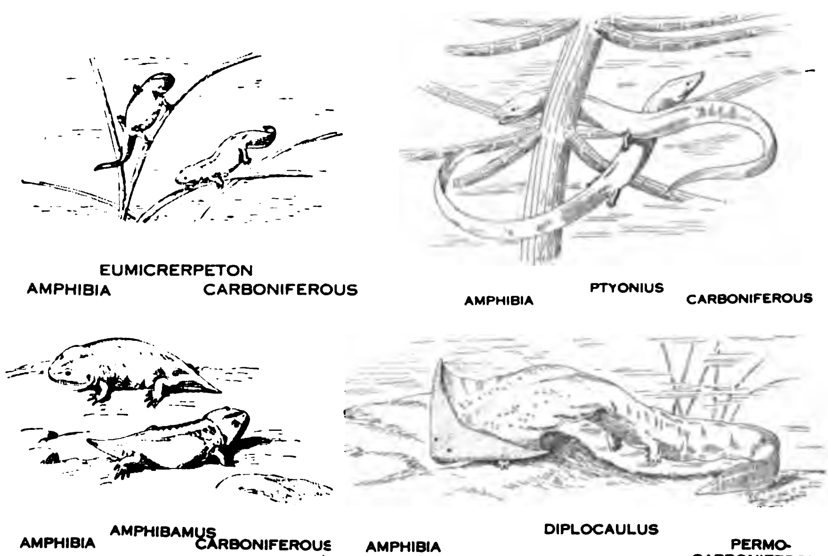


Fig. 24. Chief Amphibian Types of the Carboniferous, the early short-tailed, land-living *Amphibamus*, the salamander-like *Eumicrerpeton*, the eel-bodied *Ptyonius*, the broad-headed, bottom-living *Diplocaulus*. Restorations for the author by Gregory and Deckert.

An opposite extreme of slender body structure is found in the active predaceous types of water-loving amphibians such as *Cricotus,* of rapid movements, propelled by a long tail fin and with sharp teeth adapted to seizing an actively moving prey. This type retrogresses into the eel-like, bottom-loving *Lysorophus* with its slender skull, elongate body propelled by lateral swimming undulations, the limbs relatively useless. Corresponding to the bottom-living fishes are the large, sluggish, broad-headed, bottom-living amphibians, such as *Diplocaulus,* with heads heavily armored, limbs small and weak, the body propelled by lateral

FIG. 25. SKULL AND VERTEBRAL COLUMN OF *Diplocaulus*, a typical solid-, broad-headed Amphibian from the Permian of northern Texas. Specimen in the American Museum of Natural History.

motions of the tail. There were also more powerful, slow-moving, long-headed, alligator-like, terrestrio-aquatic forms, such as the *Archego-saurus* of Europe and the fully aquatic *Trimerorachis* of America. An extreme stage of terrestrial, ground-living evolution with marked reduction of the use of the tail for propulsion is the large-headed *Caccops,* short-bodied, with limbs of medium size, but with feeble powers of prehension in the feet. Radiating around these animals were a number of terrestrial types exhibiting the evolution of dorsal protective armature and spines (*Aspidosaurus*) ; other types lead into the pointed-headed structure and pointed teeth of *Trematops.*

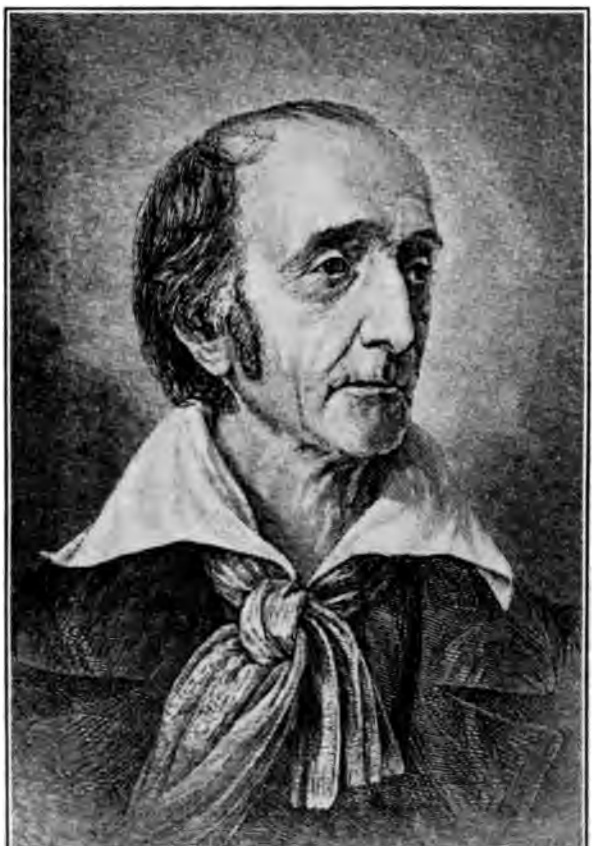
Editorial Note: The remaining parts of this Lecture will appear in December or January in book form under the title "Origin and Evolution of Life," from the press of Charles Scribner's Sons.

THE PROGRESS OF SCIENCE

THE UNITED STATES COAST AND GEODETIC SURVEY AND ITS EARLY SUPERINTENDENTS

THE centenary of the organization of the United States Coast and Geodetic Survey was fittingly celebrated in Washington last spring and the proceedings have now been issued in a volume which forms an interesting memorial of the celebration and of the great work accomplished by the survey since its foundation in 1816. The program consisted of three public sessions and a dinner. The former were held in the auditorium of the New National Museum, where fifteen addresses were given on the different phases of the survey's activities and on the relation of its work to other scientific bureaus of the government.

The superintendent of the survey, Mr.



FERDINAND RUDOLPH HASSLER.

E. Lester Jones, presided at the public sessions, and the opening address was made by Mr. William C. Redfield, secretary of commerce, the department of which the survey is now a bureau. At the banquet the president of the United States made one of the addresses. Others were by the secretary of the navy, the secretary of commerce, the minister from Switzerland, and the former superintendent of the survey, Dr. T. C. Mendenhall.

The address of Dr. Mendenhall and some of the other addresses give interesting reminiscences of the early work of the survey and its first three superintendents, portraits of whom are here reproduced by the courtesy of the superintendent of the survey. Ferdinand Hassler, born in Switzerland, trained in the best schools of Europe and practised in geodetic work, came to the United States in 1805, bringing with him a fine library of over 3,000 volumes and a collection of technical instruments such as had never before crossed the ocean. He was later appointed acting professor of mathematics at West Point and, through his friend and countryman, Albert Gallatin, was introduced to Jefferson, who had recommended to the Congress a survey of the coasts. Hassler demanded and received a salary equal to that of the head of the department to which the new bureau was assigned. It is said that the president objected, saying "your salary would be as large as that of my secretary of the treasury, your superior officer," and that he replied: "Any president can make a secretary of the treasury but only God Almighty can make a Hassler."

Hassler was sent abroad in 1811 to purchase the necessary instruments and standards of measurement but was detained in England as an alien enemy. When he returned, in 1816, the Coast and Geodetic Survey was organized, and geodetic, topographic and hydrographic work was begun. Owing to lack of appropriations by Congress, work was abandoned for twelve years, when Hassler was placed in charge of work on weights and measures, and in 1832 again assumed the duties of superintendent of the survey, which he conducted with admirable skill until his death in 1843.

Hassler was succeeded as head of the survey by Alexander Dallas Bache, a great grandson of Benjamin Franklin, whose scientific aptitudes and diplomatic skill he inherited. Graduating from the West Point Military Academy, he had attained distinction as a scientific man of originality and power, and was recommended as Hassler's successor by the scientific societies and institutions of learning. His services were continued for twenty-five years until his death in 1867; they carried forward and enlarged in important directions the work begun by Hassler.

Benjamin Peirce, the distinguished mathematician, who had conducted the longitude operations of the survey during the latter years of Bache's administration, succeeded him as superintendent, a position which he held until the age of sixty-five years, while retaining his professorship at Harvard University. The picture of Peirce shows him at the blackboard. He is said once at a meeting of the National Academy of Sciences to have spent an hour filling the blackboard with equations, and then to have remarked "There is only one member of the Academy who can understand my work and he is in South America." Under Peirce a chain of triangles extending across the continent was planned covering the whole country by a trigonometrical survey and joining the systems of the Atlantic and Pacific coasts.

We may hope that the next three superintendents of the Coast and Geodetic Survey will be men so distinguished in science as Hassler, Bache and Peirce. If this is not the case we should surely enquire into the reason. Is it because the men do not exist, or are we less competent to manage the scientific bureaus now than was the case in the earlier part of the nineteenth century? We can not believe that the human germ plasm has changed in the

ALEXANDER DALLAS BACHE.

BENJAMIN PEIRCE.

course of two or three generations, and if we do not have the men, it is because we do not select and train them. It is equally our fault if such men are not placed in charge of the scientific work of the government.

THE NEW YORK MEETING OF THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

The first of the greater convocation-week meetings of the American Association for the Advancement of Science and its affiliated societies will be held in New York City during the last week of the present month. It has been arranged that there will be held hereafter once in four years successively in New York, Chicago and Washington, meetings at which it is planned to bring together all the national scientific societies and, so far as possible, all the scientific men of the country. There will meet in New York, counting the sections of the association, more than fifty separate organizations devoted to the advancement of science, and there has not been in the history of the world a meeting of this magnitude. When the association last met in New York City ten years ago there were about five thousand members, the attendance was over two thousand, and there were nearly a thousand papers on the program. The present membership of the association numbers about eleven thousand, and the number and size of the affiliated societies has increased in proportion.

The opening session, presided over by Dr. Charles R. Van Hise, of the University of Wisconsin, will be held at the American Museum of Natural History on the evening of December 26, at which time the address of the retiring president, Dr. W. W. Campbell, director of the Lick Observatory, on "The Nebulæ" will be delivered. The registration headquarters will be at Columbia University, and most of the meetings of the sections and of the scientific societies will be held there, though there will be meetings in a number of the educational and scientific institutions of the city.

Each of the separate societies and sections is arranging sessions of interest and importance, and, as the program to be issued at the time of the meeting will doubtless fill more than a hundred pages, it is difficult to select any part for special mention. There is to be a scientific exhibit and conversazione at Columbia University, which is being organized under the charge of some fifteen different committees. There will also be a special chemical exhibit and conversazione at the American Museum of Natural History. It is expected that a joint meeting of physicists and chemists will be held at the City College with a discussion on "The Structure of the Atom and the Constitution of Matter." The four great national engineering societies, which have their headquarters in New York City, plan to hold a special meeting and a reception afterwards to those engaged in work relating to engineering. The Committee of One Hundred on Scientific Research will consider a number of important reports. The American Society of Naturalists will hold a symposium on "Biology and National Existence." Public lectures will be given by Dr. Simon Flexner, director of the Rockefeller Institute for Medical Research, and by Professor A. A. Noyes, of the Massachusetts Institute of Technology, and chairman of the committee of the government on the supply of nitrogen.

These are only a few of the events which will make the meeting of interest quite unparalleled. It is certain that men of science will make special efforts to be present, not only for the interest and profit that they will find in the meeting, but also to contribute their share to the organization of science in the United States, and to impress on the general public the dominant place that science holds in modern civilization.

The meeting will not only be important to those concerned with research,

but also to all those who are interested in any aspect of science, and it is desirable that, following the precedent of the British Association for the Advancement of Science, there may be a large attendance of those who are not professional scientific men. The association admits to membership those who are in sympathy with its aims and who wish to assist in promoting them, even though they are not engaged in scientific work. Information concerning membership may be obtained from the Permanent Secretary, the Smithsonian Institution, Washington, D. C.

SCIENTIFIC ITEMS

We record with regret the death of Dr. Cleveland Abbe, the distinguished meteorologist, and of Dr. Percival Lowell, of Boston, director of the Lowell Observatory at Flagstaff, Arizona, widely known for his work and theories on the planet Mars.

A meeting to plan a memorial to the late Sir William Ramsay was held at University College, London, on October 31. After the meeting, the director of the University College Chemical Laboratories, Professor J. Norman Collie, F.R.S., delivered a memorial lecture on "The Scientific Work of Sir William Ramsay."

Dr. Wilhelm von Waldeyer, professor of anatomy in the University of Berlin, has been raised to hereditary nobility on the occasion of his eightieth birthday.—The American Academy of Arts and Sciences on November 15 presented the Rumford medals to Mr. Charles Greeley Abbot, of the Smithsonian Institution, for his researches on solar radiation.—The degree of doctor of laws was conferred upon Thomas A. Edison over the telephone by Dr. John H. Finley, president of the University of the State of New York, at the closing session of the institution's fifty-second convocation on October 20. Mr. Edison was in his laboratory at Orange, N. J., while Dr. Finley was in the auditorium of the New York Education Building at Albany.

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